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TASK II - IDENTIFICATION OF PLANNING FACTORS AND ACTIVITIES

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TABLE OF CONTENTS

	Page
FOREWORD	ii
TASK II - IDENTIFICATION OF PLANNING FACTORS AND ACTIVITIES	
THE IMPORTANCE OF R&T - VIEWGRAPH PRESENTATION: MAY 1976	TAB A
THE IMPORTANCE OF R&T - PRESENTATION BACK-UP INFORMATION; MAY 1976	TAB B
NASA OAST ADMINISTRATIVE CONTROL PROCEDURES; JULY 15, 1976 .	TAB C
GENERAL AVIATION ADVOCACY THEME; SEPTEMBER 1976	TAB D

FOREWORD

This is Volume II of a three volume final report which consolidates the studies and analyses conducted by Operations Research, Inc. (ORI) for the National Aeronautics and Space Administration, Goddard Space Flight Center, under Contract No. NAS5-23477.

This volume contains documents generated under Task II - Identification of Planning Factors and Activities.

THE IMPORTANCE OF R&T
VIEWGRAPH PRESENTATION

Prepared by:

Operations Research, Inc.
May 1976

AEROSPACE ACCOMPLISHMENTS

CONSISTENT
TYPE SIZE ON
ALL VIEWGRAPHS

NATIONAL STRENGTH

- APOLLO DEMONSTRATED U.S. SUPERIORITY
- U.S. CURRENTLY LEADS IN SPACE & AERONAUTICS, SCIENCE & ENGINEERING
- AEROSPACE SYSTEMS ARE CRITICAL TO MILITARY CAPABILITIES AND U.S. TRANSPORTATION

RELIANCE ON SPACE

- COMMUNICATIONS INDUSTRY REVOLUTIONIZED BY SPACE
- WEATHER & CLIMATE SERVICES RELY ON SATELLITES
- IMPORTANT MILITARY APPLICATIONS
- AN INSTRUMENT OF INTERNATIONAL POLICY

ECONOMICS OF SPACE

- NASA PROGRAMS EMPLOY OVER 100,000 IN INDUSTRY
- WHOLE NEW INDUSTRIES HAVE BEEN CREATED

► SCIENCE AND TECHNOLOGY ARE VITAL ELEMENTS
OF U.S. NATIONAL VIGOR

TRENDS

U. S. LACKS/LAGS

RESOURCES

- PETROLEUM
- CRITICAL RAW MATERIALS

TECHNOLOGIES

- SUPERCONDUCTING SYSTEMS
- MHD POWER GENERATION

HARDWARE

- SUPERSONIC TRANSPORTS
- HELICOPTERS

RECENT TECHNOLOGY IMPORTS

ELECTROSLAG PROCESS USSR

TURBO TRAINS FRANCE

SILICONE CHIPS W. GERMANY

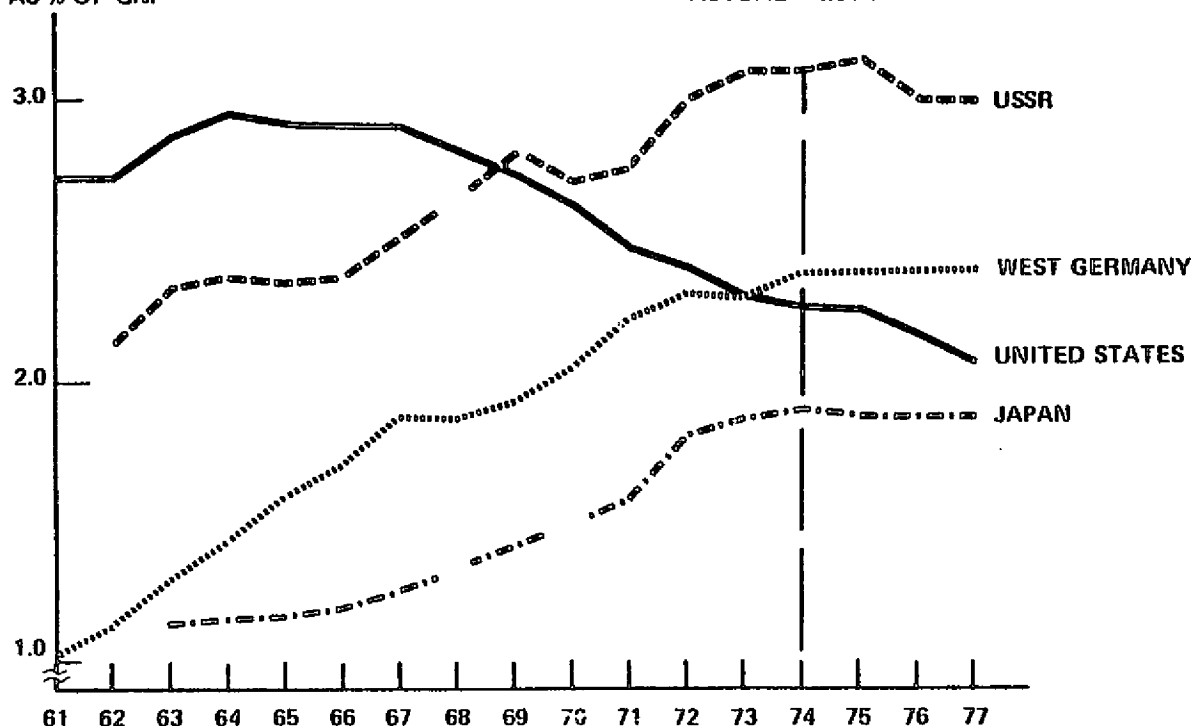
MACHINE TOOLS EUROPE

MEDICAL X-RAY U.K.

R&D INVESTMENT POLICY

R&D AS % OF GNP

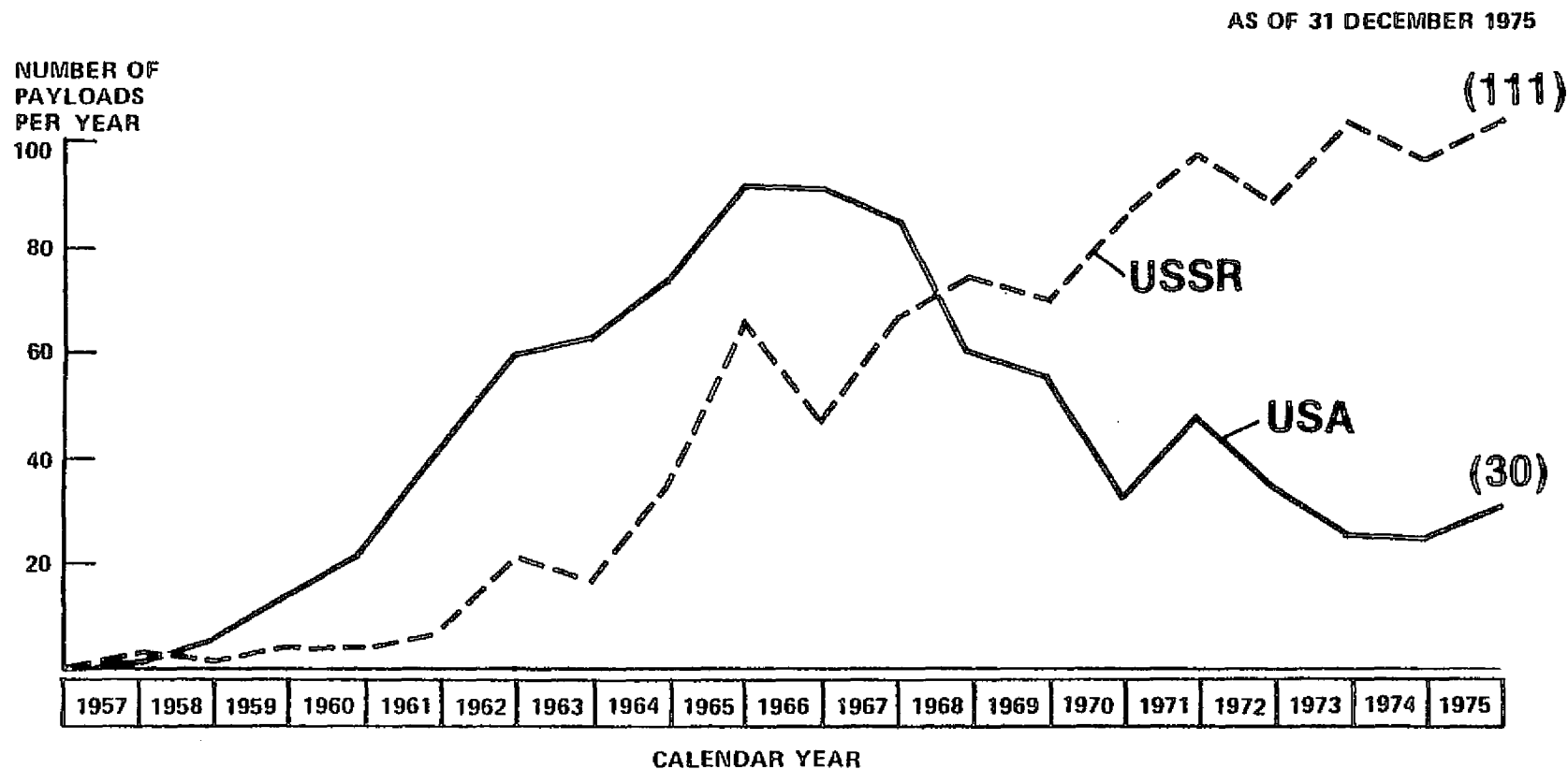
ACTUAL ESTIMATED



► U.S. RISKING LOSS OF TECHNOLOGICAL LEADERSHIP

EARTH ORBITAL, LUNAR & PLANETARY PAYLOADS

USA	863
USSR	992



► U.S. SPACE LEAD IS BEING OVERTAKEN

IMPORTANCE OF NASA TECHNOLOGY

- **AERONAUTICS TECHNOLOGY HAS CREATED A \$30 B U.S. INDUSTRY**
 - **\$7B IN BENEFITS TO U.S. INDUSTRY FROM NASA AEROSPACE TECHNOLOGY IN FOUR AREAS ALONE.**
 - **GAS TURBINES**
 - **INTEGRATED CIRCUITS**
 - **CRYOGENIC INSULATION.**
 - **STRUCTURAL ANALYSIS**
 - **THERE IS A 14 TO 1 PAYOFF OVER 10 YEARS FOR EVERY NASA DOLLAR SPENT**
 - **EACH INDUSTRIAL JOB ON NASA WORK GENERATES 1.5 ADDITIONAL JOBS**
- ▶ **NASA IS A GOOD INVESTMENT**

OPPORTUNITIES FOR MAJOR THRUSTS:

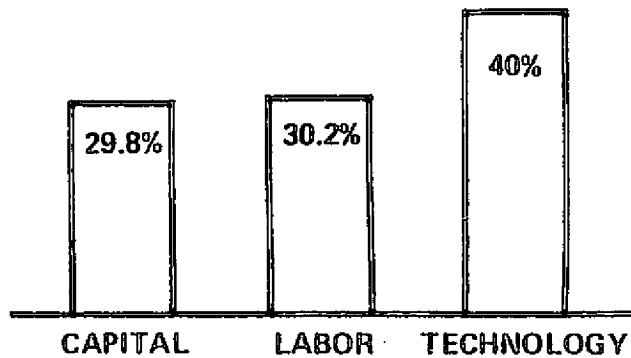
- INDUSTRIALIZATION OF SPACE
- DEVELOPMENT OF SPACE SYSTEMS FOR CIVIL NEEDS
- EXPLORATION OF THE UNIVERSE FOR NEW KNOWLEDGE
- LEADERSHIP IN AERONAUTICS AND AVIATION

► THEIR PURSUIT WILL:

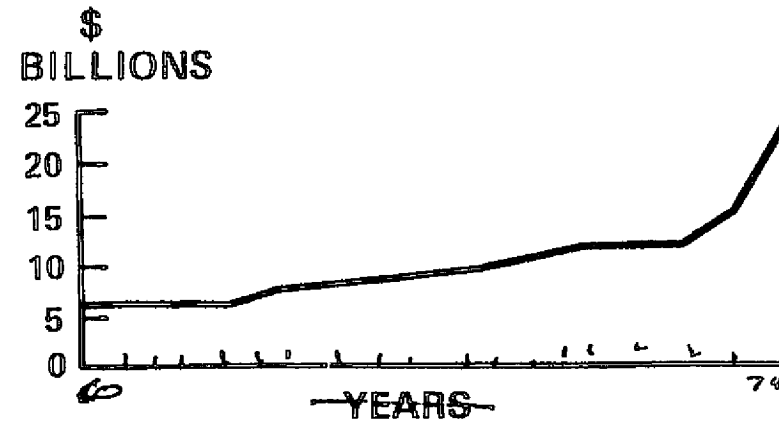
- REGAIN PREEMINENCE
- CREATE NEW INDUSTRIES
- STRENGTHEN U.S. ECONOMY
- REDRESS TECHNOLOGY BALANCE
- CAPITALIZE ON UNIQUE NASA CAPABILITIES

THE VALUE OF TECHNOLOGY

THE MAJOR SOURCE OF PRODUCTIVITY GROWTH



TRADE BALANCE OF HIGH TECHNOLOGY PRODUCTS



► PRODUCTIVITY & EXPORTS MEAN:

■ U.S. JOBS

■ INDEPENDENCE

■ STANDARD OF LIVING

THE IMPORTANCE OF R&T
PRESENTATION BACK-UP INFORMATION

Prepared by:

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May 1976

AEROSPACE ACCOMPLISHMENTS

AEROSPACE ACCOMPLISHMENTS

NATIONAL STRENGTH

- ▣ APOLLO DEMONSTRATED U. S. SUPERIORITY
- ▣ U. S. CURRENTLY LEADS IN SPACE & AERONAUTICS, SCIENCE & ENGINEERING
- ▣ AEROSPACE SYSTEMS ARE CRITICAL TO MILITARY CAPABILITIES AND U. S. TRANSPORTATION

RELIANCE ON SPACE

- ▣ COMMUNICATIONS INDUSTRY REVOLUTIONIZED BY SPACE
- ▣ WEATHER & CLIMATE SERVICES RELY ON SATELLITES
- ▣ IMPORTANT MILITARY APPLICATIONS
- ▣ AN INSTRUMENT OF INTERNATIONAL POLICY

ECONOMICS OF SPACE

- ▣ NASA PROGRAMS EMPLOY OVER 100,000 IN INDUSTRY
- ▣ WHOLE NEW INDUSTRIES HAVE BEEN CREATED

▶ SCIENCE AND TECHNOLOGY ARE VITAL ELEMENTS
OF U. S. NATIONAL VIGOR

SPACE ACCOMPLISHMENTS

- WE HAVE ACCOMPLISHED A GREAT DEAL WITH THE \$60B INVESTED OVER THE PAST TWO DECADES.

NATIONAL STRENGTH

- NASA AND THE SPACE PROGRAM HAVE BEEN A SYMBOL OF AMERICA'S LEADERSHIP TO THE WORLD. WE HAVE:
 - OVERCOME THE SOVIET EARLY START
 - LANDED MAN ON THE MOON - ON SCHEDULE, WITHIN COST
 - ENERGIZED SCIENCE AND ENGINEERING
 - EXPANDED OUR KNOWLEDGE OF THE UNIVERSE
 - BOLSTERED THE NATIONAL SPIRIT
 - DEMONSTRATED TECHNOLOGICAL AND POLITICAL SUPERIORITY
- THE U.S. IS THE LEADER IN AERONAUTICS AND SPACE

RELIANCE ON SPACE

- WE HAVE COME TO RELY ON SPACE AND AERONAUTICS

FOR COMMUNICATIONS - IN 1965 THERE WERE - 3000 (3% BY SATELLITE)

INTERCONTINENTAL TELEPHONE CIRCUITS, BY 1975 - 25,000
25% PROVIDED BY SATELLITE

FOR ROUTINE WEATHER OBSERVATION

- AGRICULTURAL CLIMATE AND WEATHER
- DISASTER WARNING
- HEALTH AND SAFETY

FOR THE BASIC TECHNOLOGY OF TRANSPORTATION -

HALF OUR AIR PASSENGERS ARE ON BUSINESS

- THE TECHNOLOGIES AND SYSTEMS CREATED CONTRIBUTE TO NATIONAL SECURITY

- COMMON INDUSTRIAL BASE
- SPACE ENVIRONMENT UNDERSTANDING
- COMMON AERONAUTICAL PROBLEMS
- MULTIPURPOSE USE OF SPACE ASSETS, E.G., SHUTTLE

ECONOMICS OF SPACE

- THE MULTIPLIER EFFECT ADDS SOME 200,000 ADDITIONAL JOBS
- IN ADDITION TO AEROSPACE SOME 360,000 WE EMPLOYED IN AIR TRANSPORTATION
- WHOLE NEW INDUSTRIES CREATED - COMSAT, SPACE BUSINESS SYSTEMS, AMERICAN SATELLITE COMPANY
- NEW MARKETS FOR
 - GROUND EQUIPMENT MANUFACTURERS - RCA, GE
 - AND
 - INFORMATION PROCESSING FIRMS
- LEAST UNDERSTOOD PRODUCT IS HIGH TECHNOLOGY
 - NEW MATERIALS
 - MANUFACTURING PROCESSES
 - PROCEDURES - CLEAN ROOMS
 - HUNDREDS OF END ITEMS - TEST EQUIPMENT, DATA SYSTEMS, POWER COMPONENTS, SOPHISTICATED COMPUTERS, AND SOFTWARE

1. AEROSPACE ACCOMPLISHMENTS

Our national investment in aerospace RD&D pays off both directly and indirectly. It has both demonstrated and added to our national strength so significantly that a number of important national and international social, political and economic functions have come to rely heavily on inputs from space programs. NASA programs stimulate economic growth by employing over 100,000 people in a high technology industry which has led to the creation of entirely new industries through technological spinoffs.

NATIONAL STRENGTH AND RELIANCE ON SPACE

Two primary determinants of a nation's strength are its leadership in various fields of human endeavor and the nation's ability to use its limited resources of land, labor and capital efficiently. The pursuit of space goals generates innovations in virtually all fields of science and technology and therefore stimulates progress in all areas not even remotely connected to the original program. Thus, landing a man on the moon, building our spaceport, tracking stations, and overall space capability took only nine years and \$20 billion and has resulted in a vastly increased scientific and technological knowledge base and spinoffs that has put portions of American industry far ahead of the rest of the world, increased our military capabilities and improved the efficiency of U.S. transportation. Examples of some uses of these spinoffs are: improved weather forecasting, the cardiac pacemaker which is an outgrowth of the miniaturized solid-state circuitry developed for aircraft, telecare cardio-alert program in Cleveland, the Intelsat (International Telecommunications Satellite System), TECH House (The Energy Conservation House), the general advancement of our aircraft industry through avionics, aeronautics and other related work, sophisticated missile, anti-missile, and anti-submarine defense systems, improved gas turbines for electricity generation, integrated circuits for consumer and industrial products, improved insulations for cryogenics, and satellite surveillance for arms control. The U.S. and other nations have come to rely on many of these space-derived developments to ensure their political, economic and social well being.

Economics of Space

NASA expenditures are relatively effective in reducing unemployment, reducing inflation and stimulating aggregate economic activity in the short run. This is because NASA expenditures are labor intensive and draws resources from an industry which in recent years has generally had significant unemployment, and unused capacity. According to a recent report, (by Chase Econometric Associates) the total number of jobs resulting from each \$100 million of NASA expenditures is 10,000 jobs. Therefore, NASA is near the top of the list of Federal expenditures in terms of short-term employment generation.

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2. Chase Econometrics Inc., the Economic Impact of NASA R&D
3. NASA, Office of Technology Utilization, "Spinoff 1976, A Bicentennial Report".
4. OAST, "AERONAUTICS Today", internal report, March, 1976.
5. _____ "Aerospace Industry - Foreign Impact". Internal Paper, September, 1975.

APOLLO DEMONSTRATED
U.S. SUPERIORITY

the spinoff stimulus

Not only have men climbed the lunar craters. Not only have robot spaceships measured other planets. Most space benefits accrue directly to us on our own planet.

Today we educate the world via communications satellites. We prospect for oil with land-resource satellites. We keep the tundra frozen with spacecraft-derived heat pipes, making the Alaskan pipeline possible. Our damaged hearts are run by pacemakers, our ailments diagnosed by computer. Highways are grooved to prevent skidding. Bridges soon may be protected from corrosion. Better lubricants, more powerful solar cells, more efficiently designed railroad cars have been spun from space technology. Thousands of technical innovations are the payoff after 18 years in space.

Examples of how our national investment in space research and technology pays off will be described here, first as social, political, and economic stimuli and then in the exploration of space for its own purposes. The "research payoff" continues with current cases of space spinoffs that affect your job, your health, your mobility, your home, your environment, and your future.

Technology: currency of foreign affairs

Few human undertakings in the modern world are so important as the development of technology. And yet few subjects are so little understood. When you think of technology you think of machines. But it should be emphasized that technology, or the practical utilization of science, today is applied outside of industrial life too. Consider, as a start, how space technology has been spun off to improve our relationships with other countries.

Technology—of which the space program has become a leading generator—is now a currency of foreign affairs. It is a tool of advanced nations and a hope for underdeveloped ones. The National Aeronautics & Space Administration has helped at least 75 countries by exchanging technical information, launching their satellites, sharing communications and data derived from our own satellites, and conducting foreign experiments on our spacecraft.

Pace setters in a free society

A free society needs pace setters in multiple activities. The alternative is mediocrity. No other technological endeavor has set—and met—as high standards as are required in the space program. The term "zero defects" is an invention of space technology in which machines must function perfectly in the almost impossible environments of vacuum and temperature extremes.

And yet all that represents just some of the indirect benefits of space technology. Space has its own purposes, targets, and destiny. Space technology already is accomplishing things that cannot otherwise be done economically, or perhaps done at all. This is happening in satellite monitoring of the weather, global communications, navigation, oceanography, meteorology, geology, astronomy, and of course exploration of the solar system.

Dollar returns from our tax penny

If you ask the man in the street how much the space program costs the country, his guess is likely to be \$20-billion a year. That's the figure he's heard and it sticks in his mind. That amount was the cost of nine years of the program to land men on the moon before the end of the decade of the sixties. As such, it was the primary cost of building our spaceport, tracking stations, and overall space capability.

It is a remarkable, often-overlooked fact that the pursuit of space goals generates innovations in virtu-

*Whatever stimulates massive scientific
will benefit all science, for what science most
can command the attention, respect*

all fields of science and technology, and therefore helps stimulate progress in areas not even remotely connected to the original program. The use of the words "virtually all" is intentional. It is difficult to imagine a scientific discipline or area of technology that has not contributed to the space program—and vice versa.

Whatever stimulates massive scientific inquiry in all disciplines will benefit all science, for what science most needs is a focal point that can command the attention, respect, and dollars of the world. With 90% of all scientists ever born still alive and working today, with the rate of scientific and technological advancement accelerating now in geometric progression, the real world of solvable problems cries for a standard bearer, a stimulus, and a goal.

If you accept this broad view of spinoff, then the many benefits attributable to the space stimulus are difficult to measure in their entirety, so thoroughly have they pervaded our lives. Yet, so many benefits have accrued that even the direct generation of new products, processes, and whole new technologies and industries is impressive.

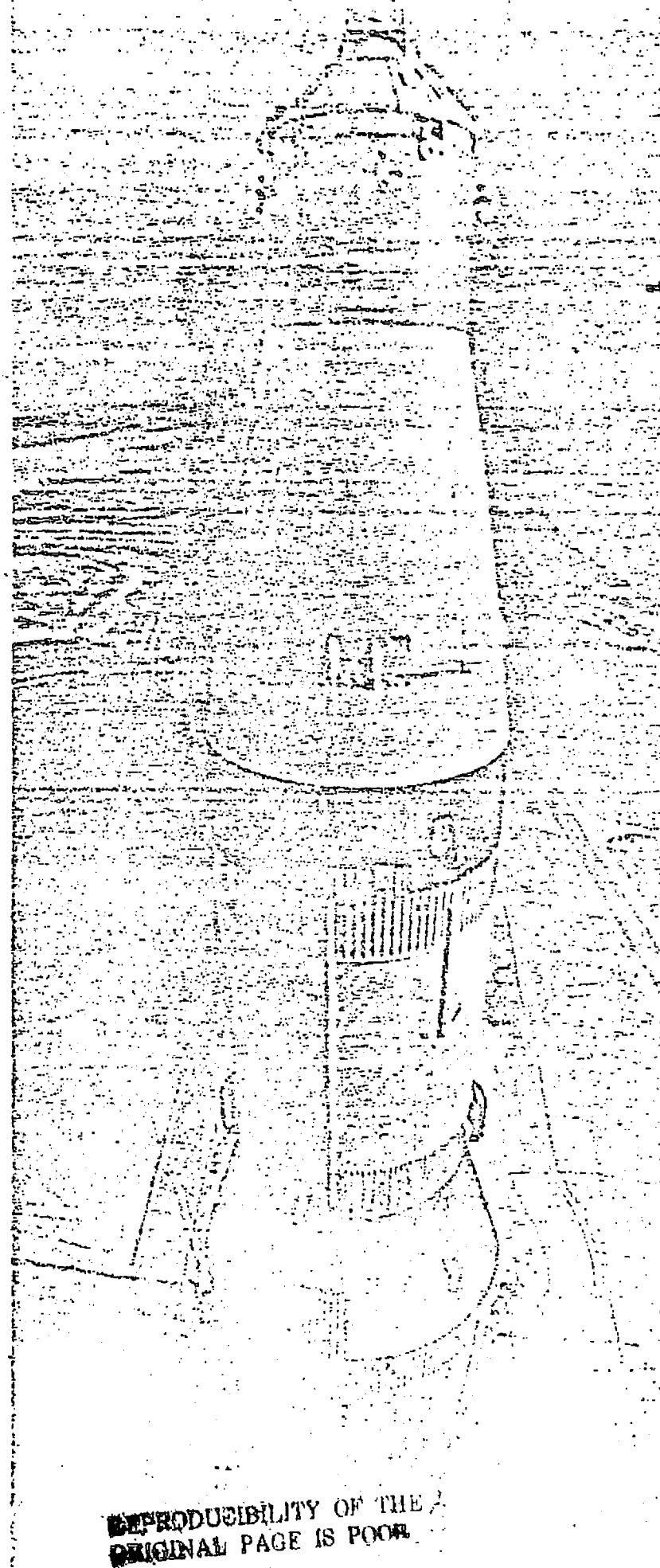
In attempting to quantify the benefits to the national economy from secondary applications of space technology, economists last year traced the spinoff of four broad NASA programs. They estimated that secondary benefits in these areas will return \$7-billion to the economy in a 14- to 20-year period—more than twice NASA's current annual budget. Another recent study showed that each new dollar invested annually on space research and development would return \$23 over a 10-year period (see "Your Job," below).

Spinoff really works—but not as an isolated phenomenon. The research payoff is a fact of modern American life, interwoven with the direct benefits of space and our entire technology. Because of spinoff, we can define space exploration as a self-funding pursuit of the unknown, the most potential-filled endeavor in history.

Some day, spinoff may acquire an even more expanded meaning. It may include new crops hybridized with plants native to other planets. Or even knowledge transferred by communicating with intelligent life in other solar systems.

Before discussing some of today's specific products that have been spun off from space technology, it may be of interest to describe just what we are spinning off from.

*in all disciplines
as a focal point that
dollars of the world.*



REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

exploring the solar system

The exploration of the solar system began with observations from space of our own planet. It started 19 years ago shortly after Sputnik roared its way into the consciousness of people throughout the world.. Since then thousands of satellites built by dozens of countries have been launched, with the U.S. maintaining space leadership by a wide margin.

It's not who's first that counts, as Columbus proved. It's who's first with a difference. The fact that Soviets were first with a satellite or that we landed men first on the moon is of little relative importance.

The difference is that we landed men six times, returning human observations that will keep scientists busy for years, and that our satellites now assist in solving a multitude of world problems. We have built a space capability and have begun the exploration of the solar system, opening a new era of civilization.

Servants in space

If outerspace exploration represents knowledge for tomorrow, the earth satellites are the workhorse machines of today. At the beginning of 1976 there was a swarm of about 750 satellites operating in earth orbit, 375 of them launched by the United States.

Among the many uses of these servants in space are weather forecasting, communications, scientific data gathering, solar observation, and prospecting and management of natural resources.

Good weather forecasting saves money. An accurate five-day forecast, which may be possible as satellite technology progresses, has been estimated to save up to \$5.5-billion yearly in the U.S. alone, and as much as \$15-billion for the entire world. The savings would be in agriculture, construction, transportation, recreation, and other industries.

Today's satellite system of weather watchers provides pictures of cloud cover over the globe both day and night. It contributes significantly to accuracy

First virtually continuous day-night photographs of a hurricane in the making were taken in 1974 by meteorological satellite in fixed orbit. Satellites are helping unravel how hurricanes and tornadoes form as first step in their possible control. Dramatic photo is hurricane Gladys stalled near Naples, Fla. in 1968. A vigorous updraft hid the storm's eye by flattening cloudtops against cold stable air of the tropopause and forming a pancake of cirrostratus 10 miles wide.



U.S. CURRENTLY LEADS IN
SPACE & AERONAUTICS SCIENCE & ENGINEERING

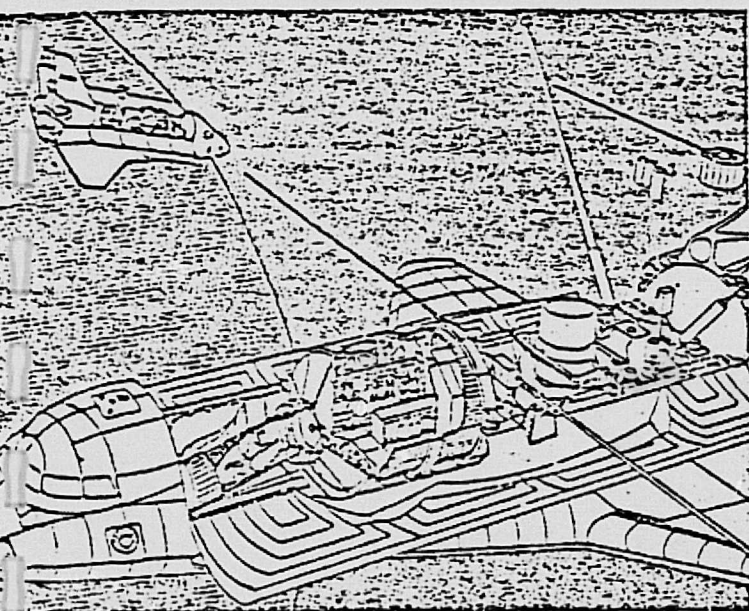
Shuttling to orbit

Following the lunar landings and using essentially the same hardware, the 100-ton Skylab space station was launched in 1973. Three missions that year and the next proved that man can live and work in space for prolonged periods. Last year, the joint U.S.-Soviet, Apollo-Soyuz linkup provided experience in docking with dissimilar equipment and languages and preparing for future space-rescue missions if needed.

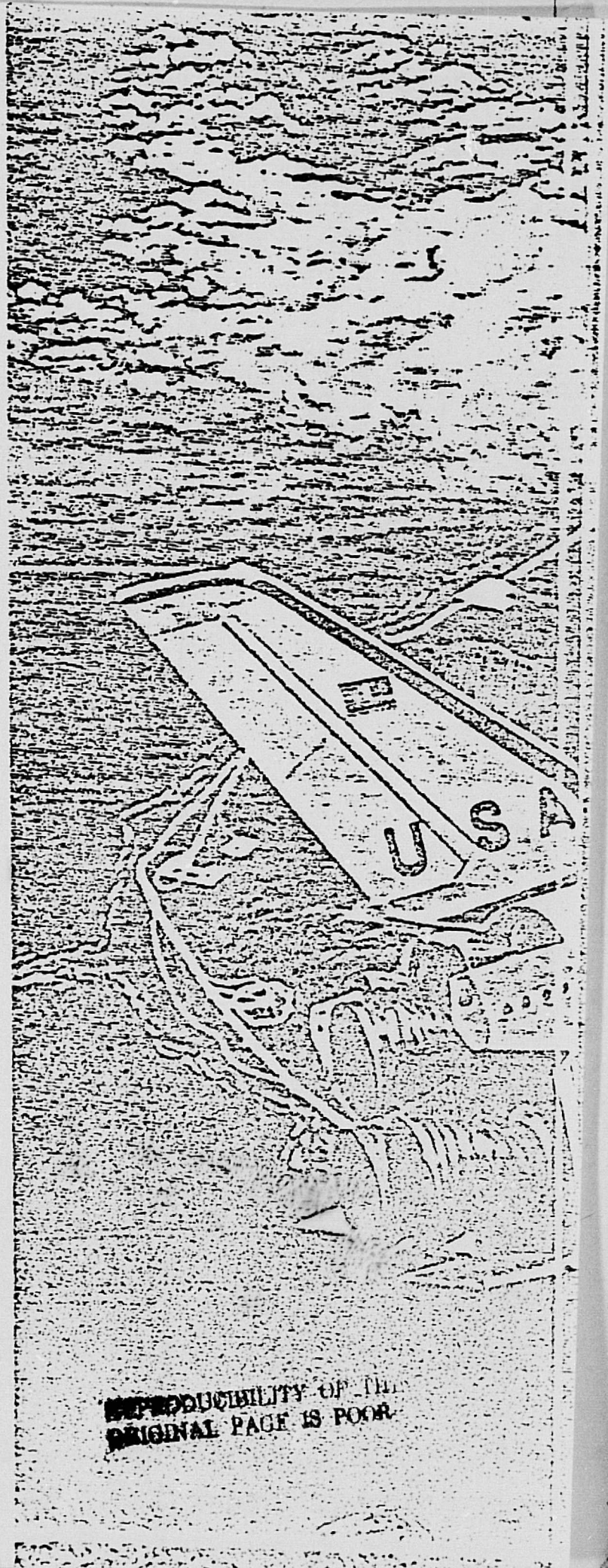
These flights also saw the beginnings of men conducting experiments in space to develop manufacturing processes in weightlessness, observe the sun from space, and monitor earth resources. One day we will make electronic components, thin films, optical devices, and even pharmaceuticals in space. And space will be the primary location for astronomy.

But a better method will have to be devised than building multi-million-dollar ship-sized rockets and then throwing them away after one use. Few considerations kill an otherwise desirable plant site quicker than lack of suitable transportation.

The space shuttle will provide low-cost transportation to earth orbit. Now under construction to be operational in 1980, the shuttle will take off like a rocket and land like an airplane. It will be the major part of a reusable space transport system that will replace most current U.S. launch vehicles.



Reusable spaceship will shuttle men and materials between earth and orbiting space stations beginning in 1980. The first of five 122-ft delta-winged ships now being assembled at Rockwell International is about size of conventional DC-9 jet, but double its weight. The shuttle will lift payload of 65,000 lbs., reducing cost to orbit per pound of payload from \$600 to \$150. "Space-lab" payload, shown in drawing above, will enable scientists to work in shirtsleeves for up to 30 days in earth orbit.



REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

our health

NASA's role in major areas of human concern is where more evident than in its myriad contributions to health. Space medicine together with innovation in remote acquisition, monitoring, and interaction of physiological processes during flight have generated technology for improving both the quality and quantity of health care.

The problem even in this advanced country is staggering. Seven of 10 Americans visit their physician at least once a year; one of 10 is hospitalized. The cost of the country's health services is some \$83 billion, roughly 7.6% of the nation's gross national product.

pacemakers that can be charged

Probably the best-known space spinoff to your ears is the cardiac pacemaker, an outgrowth of miniaturized solid-state circuitry developed for spacecraft. When the natural heartbeat becomes

irregular because of heart disease, the electronic pacemaker delivers small, regular electric shocks to pace the heart. About 30,000 pacemakers are implanted each year in the United States and a like amount in the rest of the world.

Until recently, pacemakers lasted only about 22 months, after which time their battery power is depleted, necessitating surgery to remove and implant a new device. Repeated surgery can be traumatic. It's also expensive, typically costing more than \$2,000 for each operation.

A new pacemaker developed by industrial researchers with an assist from NASA is rechargeable through the skin by inductance. Once a week the patient simply puts on a charger vest for an hour to recharge his pacemaker. Since recharging can be done frequently, only one cell is required and the size of the pacemaker has been reduced to half the thickness. Now they weigh only 2 oz.

Another advantage of the new device is that it is immune to electrical interference such as microwave ovens or automobile ignitions that sometimes stop conventional pacemakers. The development is evolving. Current research is aimed at further reducing the size and increasing its reliability.

But even better pacemakers can not prevent cardiovascular disease, the number-one killer in the U.S. that accounts for more than a million deaths a year. Many of these deaths could be prevented if firemen and other rescue workers had better training and better technology that, in effect, would deliver

the facilities of a hospital to the scene of the heart attack.

NASA now has spun off its Skylab telemetry to a "Telecare" emergency system. Telecare contains in one package all the instruments that a doctor or paramedic could reasonably want in a cardiopulmonary emergency. It contains a respiratory resuscitation system, a 15-minute oxygen supply derived from a chlorate candle that releases oxygen when burned (also a space development), an electrocardiogram display and telemetry system, a defibrillator for external heart stimulation, and a blood-pressure measuring system similar to that developed for Skylab that works even when there is high background noise.

Telecare units now are being used in ambulances in Houston, Cleveland, and other cities, as well as in a demonstration remote-care program in the 4,300-square mile Papago reservation in southwest Arizona where 10,000 Indians live.

The cardio-emergency alert

Telecare also is an important ingredient in a new NASA-assisted cardio-alert program in Cleveland. Here, firemen trained as paramedics telemeter a heart-attack victim's data to the Fairview General Hospital's Kemper coronary unit. Listen:

PM: (paramedic): *Kemper, This is Squad Two . . . We're at the victim's side. A 62-year old woman. We have no respirations yet.*

KU (Kemper coronary unit): *Did you institute CPR?*

PM: *Yes. We're starting right now. (CPR is cardiopulmonary resuscitation, or artificial breathing and blood circulation.)*

KU: *Is there a pulse?*

PM: *Negative.*

KU: *Continue CPR. Do you think someone can start an IV of 5% dextrose and water?*

PM: *Five percent. Okay. (An IV, or intravenous infusion, must be set up as fast as possible. If the heart isn't pumping blood to fill the veins, they'll collapse, making it difficult to medicate the patient.)*

KU: *Are you hooking the patient up to the monitor?*

PM: *We're beginning.*

KU: *Is she responding at all?*

PM: *Wait a moment. No. No pulse.*

KU: *Try a precordial thump (a blow to the chest). How long has she been unresponsive? Can you hook her up to the monitor yet?*

Within one minute, the paramedics begin transmitting the electrocardiogram, which is printed out and taped at the hospital. In the scene described, adapted from the Fairview General Hospital publication, the paramedic-trained firemen shock the heart electrically into a more normal pattern. They also administer drugs, have the hospital notify the patient's doctor and retrieve her records, and of course

ellites maintain a 24-hour watch on most of the Western Hemisphere, transmitting data to produce a picture every 30 minutes.

Improved communications through satellites have enabled ships and airplanes to find faster, safer routings around storms, ice, and other obstacles. Communications satellites have widened television coverage, extended education and medical care to remote regions, and even have reduced the cost of overseas phone calls.

The Intelsat, or International Telecommunications Satellite System, continues to grow in capability. This organization of 91 nations has brought the advantages of telecommunications to most of the world. The system today consists of more than 6,000 telephone circuits among 110 earth-station antennas located in 66 countries, and it is growing with new launches of improved satellites each year.

Larger applications technology satellites, powerful enough to broadcast directly from orbit into countless television sets, are being placed in geosynchronous orbit so that they'll hover, in effect, over a fixed spot on earth. The latest, the ATS-6, was launched in May 1974 and has performed flawlessly since. It has enabled physicians to conduct medical consultations in remote areas and brought high school and college courses to students in isolated Appalachian and Alaskan communities.

Dr. Wernher von Braun, president of the National Space Institute and vice president of Fairchild Industries Inc., which built the satellite, describes a typical scene. A seven-year old girl in a remote Alaskan village of 425 people had caught her hand in the wringer of an old-fashioned washing machine.

A doctor at a hospital in Tanana, several hundred miles distant, flipped a few switches and the badly frightened little girl appeared on the screen.

"Hold up your sore hand," the doctor said. "Now hold up your other hand and let me see if you can wiggle your thumbs."

Both could see each other. The isolated girl no longer was isolated. Not only could the doctor allay the girl's fear, but he could diagnose and treat her almost as well as if they were in the same room. He prescribed to the native nurse how to clean, bandage, and resplint the broken thumb.

Last May, a year after its launch, the 1.5-ton satellite was moved 8,000 miles to serve the people of India. Here, where a great many of the half-billion population live in villages and rural areas and almost none has ever seen a TV set, educational and medical telecasting may be the only realistic answer to improving the lives of an eighth of the people on earth.

The Indian government now has begun using ATS-6 to beam instructional television programs to some 5,000 villages and cities in seven states. India views satellite education as the only means to break the back of its widespread illiteracy.

Our lunar legacy

Both satellites and men have special roles in exploring the other worlds of our solar system. Where it is feasible for man to go, it is difficult to conceive of an instrument more capable. The human body has been defined as "a 10-cycle closed-loop, sensing, computing, and performance system in a 0.1-ton chassis with a 0.1-horsepower motor." Only such "equipment" could grasp the significance—and the adventure—of the moon's many complex phenomena.

When Neil Armstrong and Buzz Aldrin landed in the Sea of Tranquility the morning of July 20, 1969, about 1.5-billion people—almost half the population of the earth—were able to watch it by satellite-relayed television. Never before (or since) had so many human minds been concentrated at the same time on one activity. Man's first expedition to another world had enormous psychological and philosophical impact. It was a symbol of both human aspirations and inter-dependency. When we see our planet televised from the moon, the fact that it is finite, beautiful, and a single object, instead of 145 distinct nations, becomes overpowering. It may be trite to say, but true, that if spaceship earth sinks we all sink with it.

A second, even greater result of the expeditions to the moon was its prominent role in the beginning of a vast scientific awakening. Like all scientific endeavors, the practical benefit to us in our homes and lives will occur in the future. But we already have learned more about the moon and the origin and evolution of the earth through the six manned lunar missions than has been learned since the dawn of history. This abundance of scientific understanding, supplemented by robot probes to the planets, is rapidly advancing the earth sciences through a new field of comparative "planetology." With the world running out of oil and other minerals, the new knowledge couldn't come at a better time.

A third part of our lunar legacy reflects the primary intention of the Apollo flights. They were first steps, "travel engineering" missions, if you will, carried out to design and improve the equipment, to learn how to travel to the moon and back safely, to conduct what were essentially interplanetary expeditions—in short, to build a manned space capability.

To expect more than that psychological impact, more than that bountiful scientific harvest, and more than that engineering capability would be as though we lived at the end of the 15th Century and complained that Columbus failed to return sufficient quantities of gold from his first trips. No one dreamed of limiting future voyages then.

your home

Your home is a prime beneficiary of space technology. New building materials, better use of existing materials, as well as solar energy, fire-prevention techniques and tools, and a variety of household products all have been spun off from our national investment in space.

Builders and manufacturers of homes and housing equipment constantly strive for new methods and materials to survive in the highly competitive marketplace. Probably the most significant opportunity for change in houses over the next few decades will be in energy management. Our homes consume about 20% of the energy used in the United States each year—an amount almost equal to all imported crude oil.

Why not show builders, manufacturers, and homeowners how space spinoffs relate to home improvements? A dramatic way to do that would be to construct an actual house utilizing as many of the new developments as possible.

Planning for such a house has been under way for some time, and NASA will build a demonstration house during this bicentennial year at its Langley Research Center near Hampton, Va.

The Energy Conservation House being built at NASA near Hampton, Va. utilizes solar collectors, waste-water recycler, solid-state appliance controls, and many other space spinoffs. Demonstration house will be open to public this bicentennial year.

Now: the 'Tech House'

The demonstration house is called TECH, standing for The Energy Conservation House. Unlike past "houses of tomorrow," Tech House emphasizes cost effectiveness. It is not only a compilation of space spinoffs. Rather, Tech House integrates technical developments expected to be commercially available by 1987.

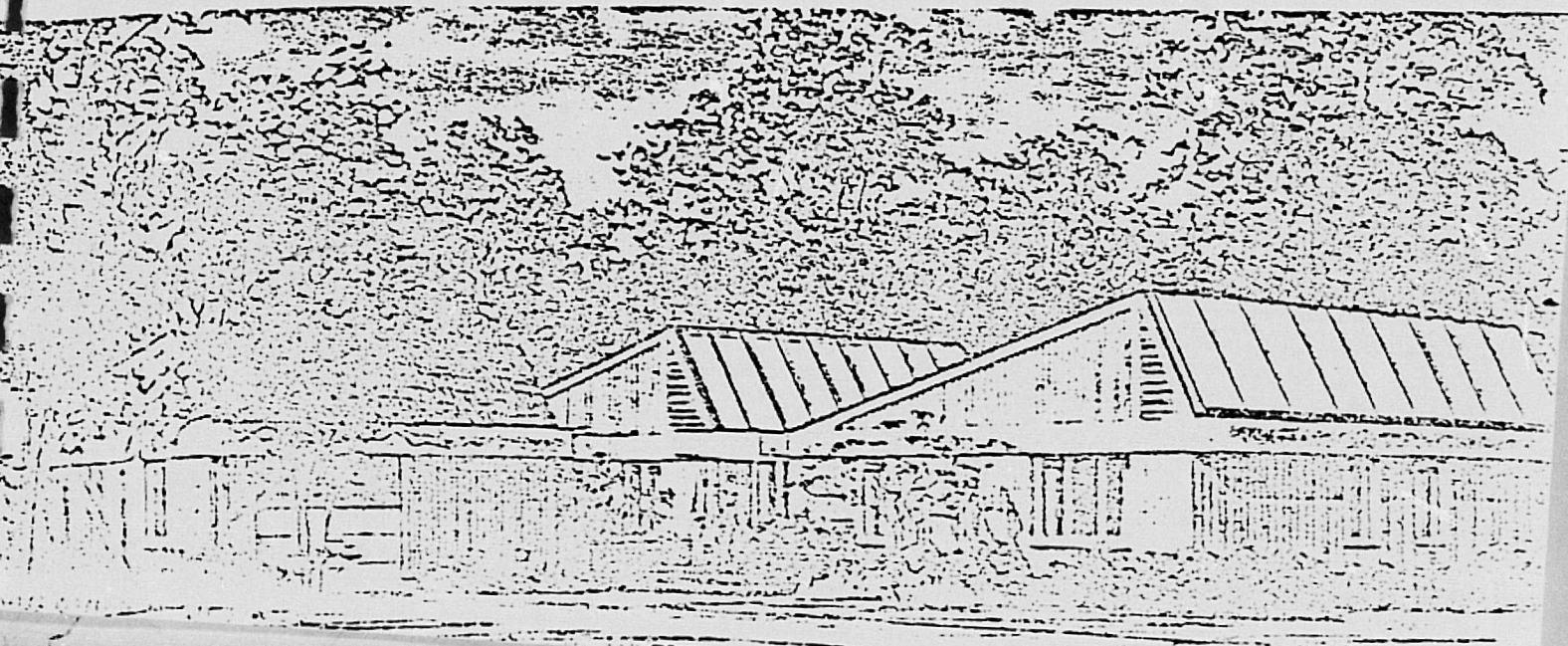
The 1,500-sq-ft building contains a living room, kitchen-dining room, three bedrooms, two bathrooms, laundry, garage, and an outdoor living area. Tech House will be tested by being occupied by a family for at least a year. Afterwards, it will be opened to the public.

NASA established some stringent criteria for inclusion of new developments in the house. For instance, initial costs of improvements must be repayable to a buyer through energy or other savings effected by the improvements themselves over the life of an assumed 20-year mortgage.

Tech House maximizes energy savings. Heating is provided by solar collectors and a nighttime radiator system using a heat pump. The house even partially reclaims waste water. Wall, roof, floor, and window sections, as well as home appliances, were studied to determine which components provide the greatest net savings.

Many of the energy-reduction advantages of Tech House are made simply through good design. For instance, the long axis of the rectangular house is oriented east-west with large south-facing glass areas. The garage is positioned to protect the house from the north wind. Two interior fireplaces, added for aesthetic reasons, are provided with glass doors to reduce heat loss through chimney flues. Doors between sleeping and living areas furnish better zone-temperature control.

Even the landscaping is designed in accordance with a new concept called "solarchitecture" that



GENERAL ECONOMY

Aerospace manufacturing sales of \$26 billion accounted for 1.9% of the GNP in 1974. Aircraft and engine sales accounted for \$14 billion of this total, and are increasingly important to this sector. Total sales of air transportation services amounted to \$14.7 billion in 1974. A total of 514,000 people were employed in the manufacture of aircraft and engines and another 363,000 in the provision of air transportation services in 1974. Some 250,000 people are employed directly in general aviation, and it should be noted that three-quarters of a million Americans are pilots. Additional impacts of aeronautics on the overall economy, not easily quantified, are implicit in such factors as the value of travelers' time, the value of supporting services and the contribution of aeronautical systems and services to national productivity.

U.S. INTERNATIONAL TRADE

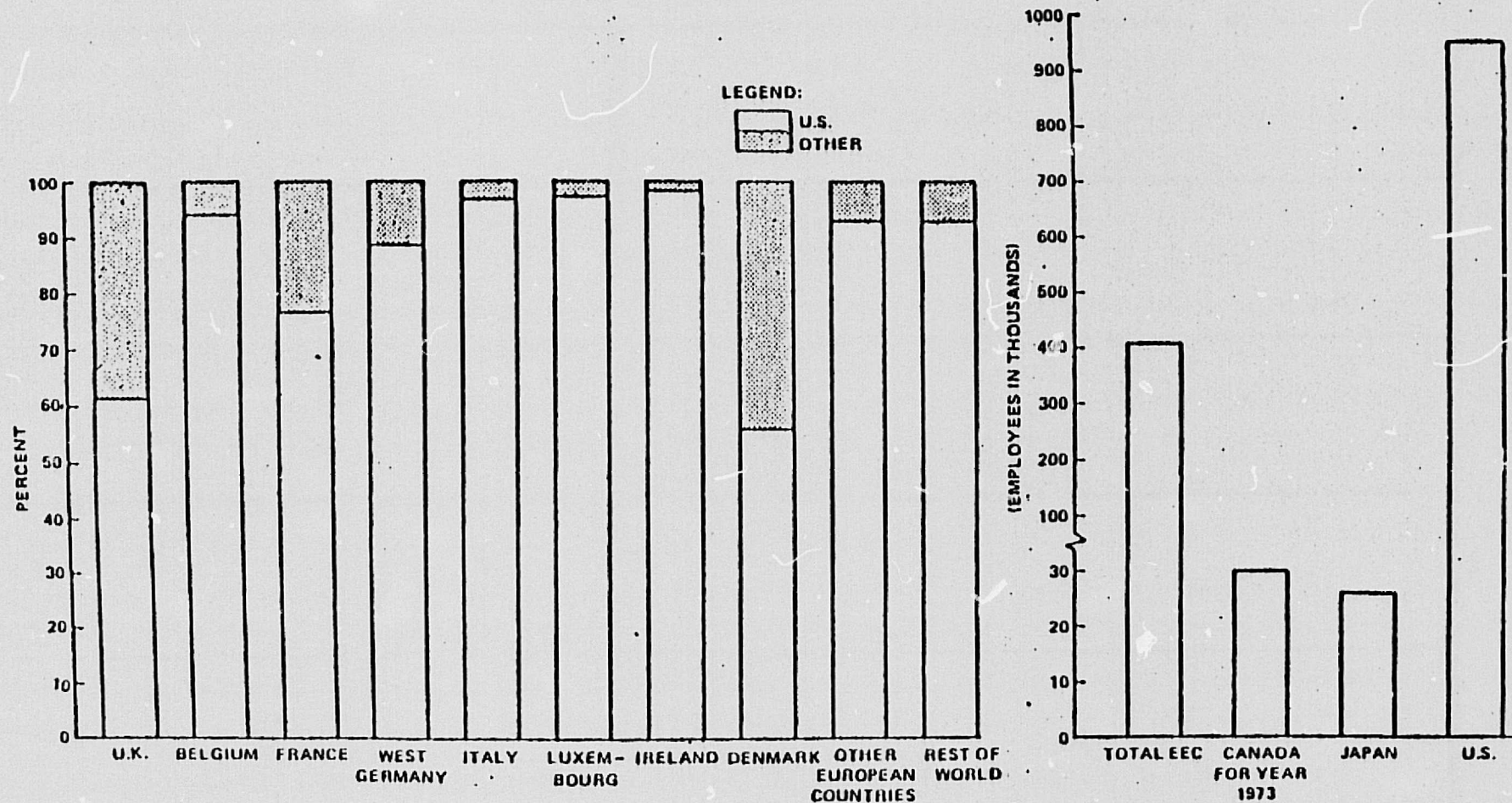
In 1974, U.S. aeronautical exports (aircraft, engines, parts) amounted to 6.9 billion dollars, 5.3 billion of which were for civil aircraft. The 6.9 billion dollars constituted most of the 7.1 billion dollars of aerospace exports which accounted for 7.2% of the total U.S. exports of 97.9 billion dollars. By contrast, aerospace imports amounted to only 700 million dollars. To place these exports in perspective, Figure 3 displays the overall U.S. trade balance since 1960 and shows trade balances for other product groups which were the largest contributors to the 1974 trade deficit. Only agriculture with its 11.6 billion dollar balance had a positive balance greater than aeronautics. It should be noted that the 25,000 people and 8000 aircraft engaged in agricultural flying contributed immensely to that surplus. It is evident from these considerations that aeronautics related exports are extremely important to offset U.S. purchases of foreign goods, and to generate foreign credits required to import energy, basic metals and other materials required for durable good production.

Figure 4

U.S.A. MARKET DOMINANCE

CIVIL AIRCRAFT IN USE AND ON ORDER AS OF MAY 1974

AEROSPACE EMPLOYMENT

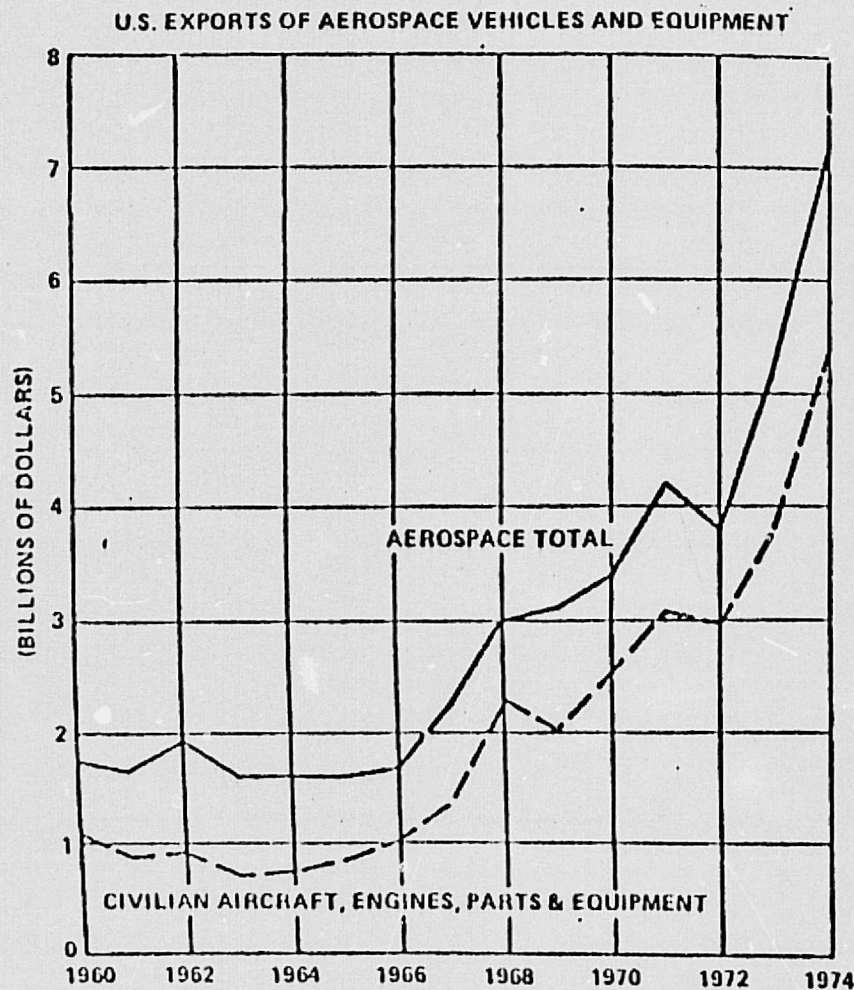


SOURCE: COMMISSION OF THE EUROPEAN COMMUNITIES:
 THE EUROPEAN AEROSPACE INDUSTRY--
 POSITION AND FIGURES-III/D/3 FEB. 1975

NASA, HQ BX 76-1281111
 11-20-76

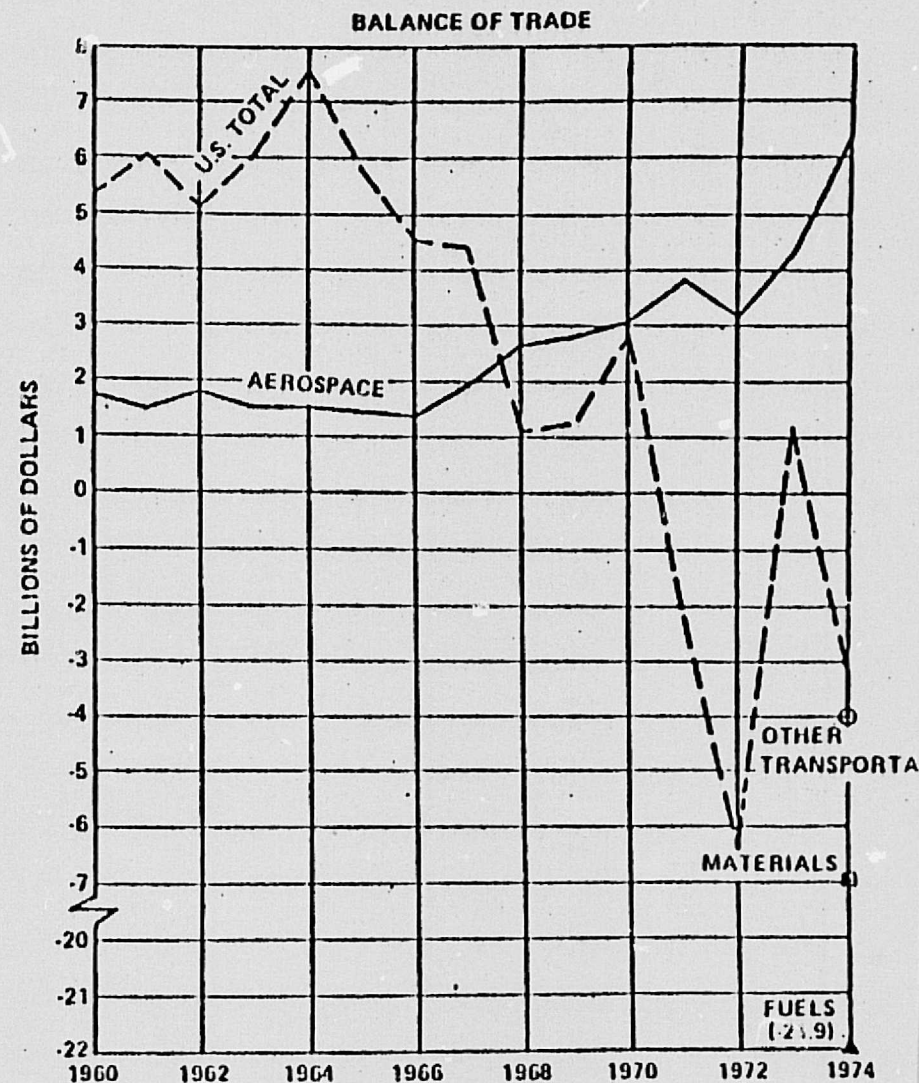
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Figure 3
TRADE



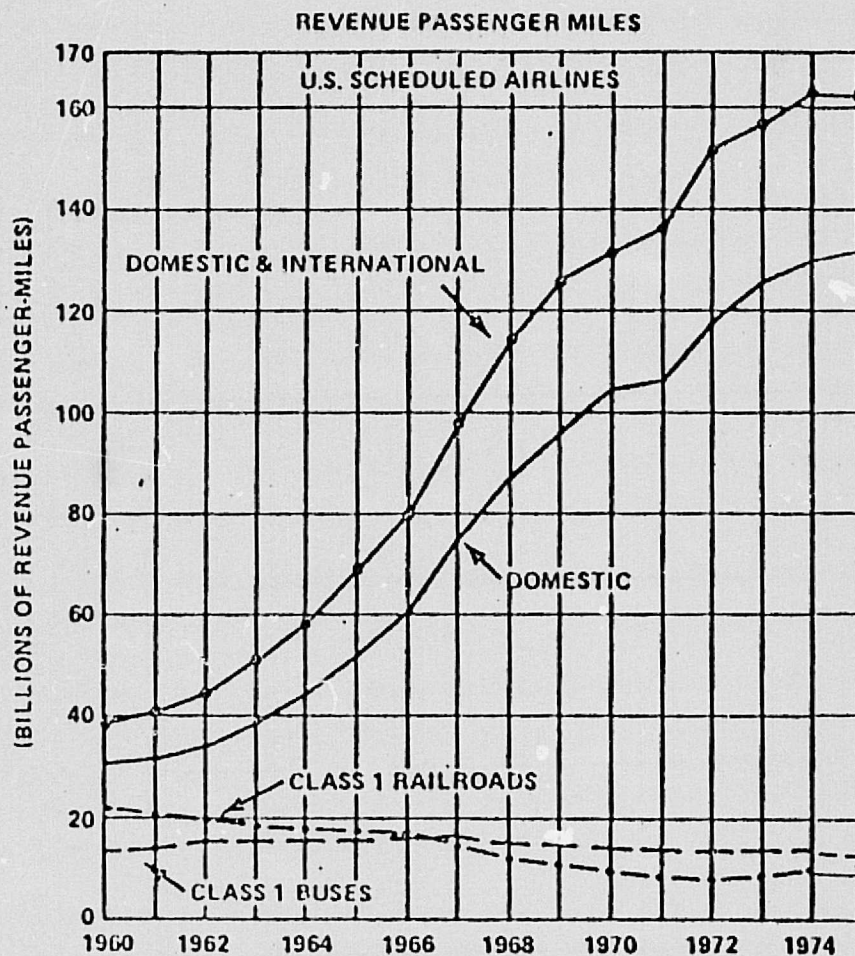
SOURCE: AEROSPACE FACTS & FIGURES 1975/1976

NASA HQ RX 76-1280(11)
11-20-75

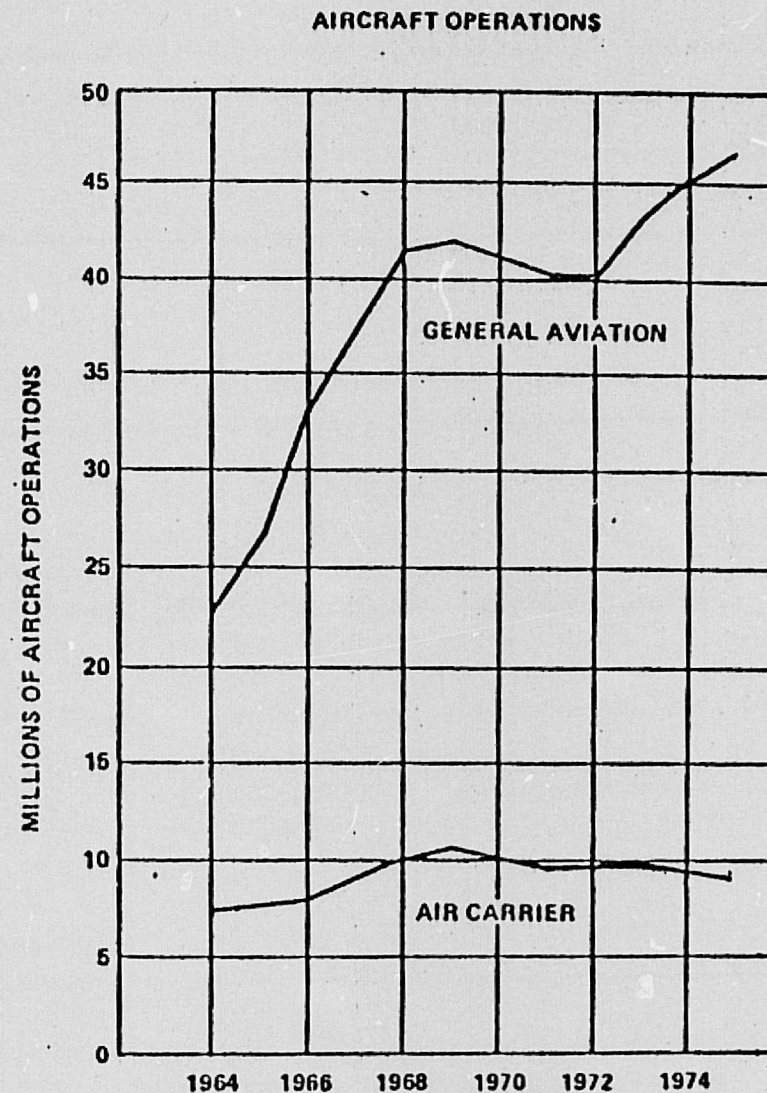


SOURCE: U.S. DATE
DOC OVERSEAS BUSINESS REPORTS, ODB75-22
APRIL 1975
AEROSPACE DATA - AEROSPACE FACTS & FIGURES 1975/197

Figure 1
TRANSPORTATION SERVICES



SOURCE: AIAA, AEROSPACE FACTS & FIGURES, 1975/1976
 AAR, YEARBOOK OF RAILROAD FACTS, 1975 EDITION
 AMTRAK OPERATIONS BEGAN ON MAY 1, 1971
 AUTO-TRAIN STATISTICS INCLUDED BEGINNING
 WITH 1972
 NAMBO, BUS FACTS, 1974 STATISTICAL SUPPLEMENT



SOURCE: DOT, FAA AIR TRAFFIC ACTIVITY
 CALENDAR YEAR 1975

85% TRAVEL BY AIR

Figure 1. Sales and Employment

Aerospace Industry Sales

Aerospace Sales (\$......)

1973 . 24,808

1974 . 26,286

1975 . 28.4

N.Y. Times 1/2/76

Aircraft, Aircraft Engines & Parts

Net Sales (\$......)

1973 . 12,278

1974 . 13,504

1975 . 15.8 (prel.)

Employment

AIRLINE

Total Aerospace Employment

1973 . 948,000

1974 . 965,000

362,700

1975 - 943; 946,000 by end of year

Aircraft, Engines, Parts & Equipment

1973 . 513.9

1974 . 532.0

1975 . 514.4

AIA / A. SKAGGS

III. IMPACT OF FOREIGN COMPETITION

INTRODUCTION

The United States dominates the aerospace industry in the free-world in numbers of industry employees, sales, and productivity. The last full year of comparable data is 1973. These data show that:

- U.S. employed 948,000 people in aerospace industry.
This is 2-1/3 times more than the 406,605 employed
by all the Common Market (EEC) countries combined.

In terms of adjusted European Accounting Units, U.S. aerospace sales were 75.8 percent of the total sales made by the free-world countries in 1973. EEC countries accounted for 17.6 percent. See Appendix A for explanation of European Accounting Units.

Over 97.0 percent of U.S. aerospace exports are aircraft and engines, therefore, it is this area that must be isolated and examined.

- U.S. employed 514,000 people (54.2 percent) in manu- *facturing*
facturing aircraft and engines.
- The major part of the EEC countries work force, *291,703*
291,703 employees (71.7 percent) are employed in
aircraft and engines.

- Using European Accounting Units, U.S. aircraft manufacturers in 1974 provided:
 - Over 94 percent of the value of all civilian transports in the world-wide airlines.
 - Over 86 percent of the number of all civilian transports in the world-wide airlines.
- Airlines of European countries (excluding U.S.S.R.) use over 25 percent of the value of all civilian transports in the world-wide airlines. U.S. airlines use 48 percent.

U.S. productivity for 1973 - sales per aircraft worker - based on adjusted European Accounting Units was considerably higher than attained by EEC countries, Canada or Japan.

- U.S. - 25,949
- EEC countries - range from 9,330 in United Kingdom to 21,591 in Netherlands
- Canada - 22,626
- Japan - 14,722

There appears to be great potential opportunity for the EEC countries, Canada and Japan to increase their share of the world-wide aircraft market and reduce their reliance on U.S. aircraft by increasing productivity. This together with the expanding multinational consortiums, government instrumentalities, increasing government subsidization, and possible government economic pump-priming measures^{1/} possess a real threat to the U.S. dominance of the aerospace industry.

AEROSPACE EMPLOYMENT

Aerospace employment in the U.S., as shown in Table 2, peaked out in 1968 when aircraft output was at a post-Korea high. Employment in 1974 is the highest since 1970. Of the 965,000 employees in 1974, 532,000 or 55.1 percent were employed in aircraft. Approximately 263,000 of these employees with payroll

^{1/} Business Week, 1 September 1975.

AEROSPACE SYSTEMS ARE CRITICAL
TO MILITARY CAPABILITIES AND
U.S. TRANSPORTATION

inates the market for landing gears. ROHR INDUSTRIES is the major factor in the power package field, i.e., the assembly of the engine, nacelle, and pylon. SIERRACIN specializes in windshields and canopies. BENDIX, a multi-industry company, has carved out a niche in hydraulic systems.

Avionics still fastest-growing section

One of the fastest-growing sectors of the subcontractor market is in avionics. This portion is made up of all the control instruments for guidance, take-off, and landing that are essential components of spacecraft, missiles, and aircraft. Further, avionics is

often the term used to describe auxiliary electronic gear and sometimes ground-based control systems. The entire avionics field is diffused and may account for as much as 20% of aerospace industry sales. This figure is growing, as the proportion of guidance equipment on aerospace vehicles climbs because of advances in radar for military and commercial applications. Avionics may actually account for as much as 40% of the cost of a tactical missile where accuracy is more significant than sheer explosive power.

There are numerous avionics and guidance system producers. Among the most prominent are RAYTHEON, BENDIX, HONEYWELL, SPERRY RAND, IBM, and the Collins Radio subsidiary of ROCKWELL INTERNATIONAL.

FINANCIAL

Canadian takeovers a minor threat

Traditionally, production in Canada of American aerospace products has accounted for 4%-5% of aerospace industry sales. In the last few years, there has been a growing feeling of nationalism in Canada toward American-based firms operating there. In 1975, this na-

tionalism spread to the aerospace industry. Specifically, the Canadians plan to buy American subsidiaries in Canada.

To this end, GENERAL DYNAMICS in January 1975 granted the Canadian Government an option to purchase its Canadair subsidiary (a maker of reconnaissance planes) by December 3, 1975. If exercised, the purchase price would be \$36.7 million, plus a portion of future profits up to \$1,500,000. In early October, Canada had not yet acted on this proposal. On October 1, however, Canada reported negotiations with McDONNELL DOUGLAS possibly leading to purchase of MD's Canadian unit. Douglas Aircraft of Canada makes wings for the DC-9 and DC-10 commercial jets. As in the case of GD, MD seized the initiative by making its own sale proposal. The company would sell Douglas of Canada if (1) the Canadian Government contracted to purchase 127 F-15 fighters (at a cost of over \$2 billion) at the rate of three a month starting in July 1978; and (2) MD was granted a minority interest in a new Canadian company to be formed from Douglas, Canadair, and De Havilland of Canada (already owned by the Canadian Government). MD would then allow the new company to produce 20% of the airframe of the F-15 fighter after 1978.

Income accounts of 65 aerospace companies (In millions of dollars)						
Year	Net Sales	Net Operating Profit	Income Before Taxes	Federal Income Taxes	Net Profit	Cash Dividends
1974	31,324	1,823	1,451	582	938	299
1973	29,494	1,619	1,449	593	855	284
1972	24,838	1,254	1,103	494	609	283
1971	23,566	893	761	338	423	242
1970	25,505	980	831	380	501	264
1969	26,392	1,493	1,433	629	804	337
1968	26,852	1,661	1,606	749	857	305
1967	22,739	1,152	1,099	489	610	228
1966	19,224	1,076	1,046	473	572	192
1965	16,073	997	984	460	524	185

Sources: Federal Trade Commission and Securities & Exchange Commission.

Aerospace employment (In thousands)				
Year	Total		Production Workers	
	Number	% Change	Number	% Change
1974	965	+ 1.8	478	+ 0.6
1973	948	+ 2.8	475	+ 4.9
1972	922	- 3.0	453	- 5.6
1971	951	-18.4	480	-20.5
1970	1,166	-16.8	604	-19.0
1969	1,402	- 6.7	746	- 7.6
1968	1,502	+ 1.2	807	+ 0.4
1967	1,484	+ 7.9	804	+10.0
1966	1,375	+17.0	731	+22.4
1965	1,175	- 2.8	597	- 0.5

Source: Aerospace Industries Association, based on Bureau of Labor Statistics and Bureau of Employment Security data.

Elimination of DISC credits possible

In 1971, Congress established a tax-easing device called the Domestic International Sales Corp. (DISC). The purpose was to stimulate export of goods to foreign countries, thus increasing employment at home. The Office of Management and Budget in March 1975, however, issued a report critical of DISC, claiming substantial loss of Federal tax revenues. The Treasury Department, in addition, estimates that DISC tax deferrals grew to \$1 billion in 1974, from about \$350 million in 1972, and will likely reach \$1.3 billion in 1975. Repeal proposals now pending would not only eliminate these benefits, but also would seek recapture or repayment of deferred DISC taxes.

MILITARY SIGNIFICANCE

The key role of aeronautics in defense has been demonstrated in several major wars and, perhaps more importantly, in the maintenance of peace during the "Cold War" and other periods of tension. Major military powers are dependent upon air logistics support for forces deployed worldwide; for the integration, control and support of strategic and tactical operations directly in the battle zone; and for interdiction of enemy supply routes. Aeronautical technology has also provided the basis for the equally vital missile, anti-missile and anti-aircraft defense systems. An increasing segment of the U.S. defense budget is directed toward research, development and production of aerospace systems of ever-increasing sophistication.

4

An indicator of the importance of aeronautics to U.S. defense is the allocation by DOD of over one-third of its RDT&E funding to aerospace; approximately \$1.8 billion of these expenditures are for aircraft in FY 1976.

CURRENT EVENTS

A. SATELLITE SURVEILLANCE AND ARMS CONTROL

- SITE INSPECTION WAS THE STUMBLING BLOCK IN ALL ARMS CONTROL UNTIL SATELLITE SURVEILLANCE MADE THE QUESTION ACADEMIC.
- SATELLITE SURVEILLANCE IS CURRENTLY OUR FIRST LINE OF DEFENSE AGAINST A SURPRISE ICBM ATTACK.

FUTURE TRENDS

A. TECHNOLOGY VS. NUMERIC SUPERIORITY

- OUR NAVY IS CURRENTLY NUMERICALLY SMALLER THAN THE RUSSIAN NAVY
- THIS TREND IS EXPECTED TO CONTINUE
- WE MUST COUNTER THIS TREND WITH CONTINUED TECHNICAL SUPERIORITY IN AREAS SUCH AS NUCLEAR SHIPS, ASW, MISSILES

THE NEED FOR IMPROVED WORLD WIDE SURVEILLANCE AND COMMUNICATIONS

- THE NEW RUSSIAN NAVY IS FOR THE FIRST TIME AN ALL-OCEAN WORLD WIDE NAVY
- WE MUST COUNTER THIS THREAT WITH AN EVER INCREASING NUMERIC INFERIORITY
- THIS CALLS FOR VASTLY IMPROVED SATELLITE SURVEILLANCE, COMMUNICATIONS, AND INFORMATION HANDLING.

Heat pipes for Alaskan oil

Oil from Alaska's rich North Slope fields will be transported with the help of a truly revolutionary heat-pipe device developed through the space program. It is being used to keep the ground frozen along the 798-mile pipeline, saving hundreds of millions of dollars and protecting the tundra environment.

While heat-pipe principles have been known since World War II, it wasn't until spacecraft were built that heat pipes were developed for cooling on-board electronic packages. Satellites use them routinely. So did Skylab.

A major construction problem in the arctic is posed by the seasonal freeze-thaw cycle of the permafrost soil. Frost-heaving, which can raise structural

piling by as much as 18 inches in one year, is followed by uneven settling during the summer thaw. The enormous forces involved literally can tear a pipeline apart, spewing hot oil over the countryside.

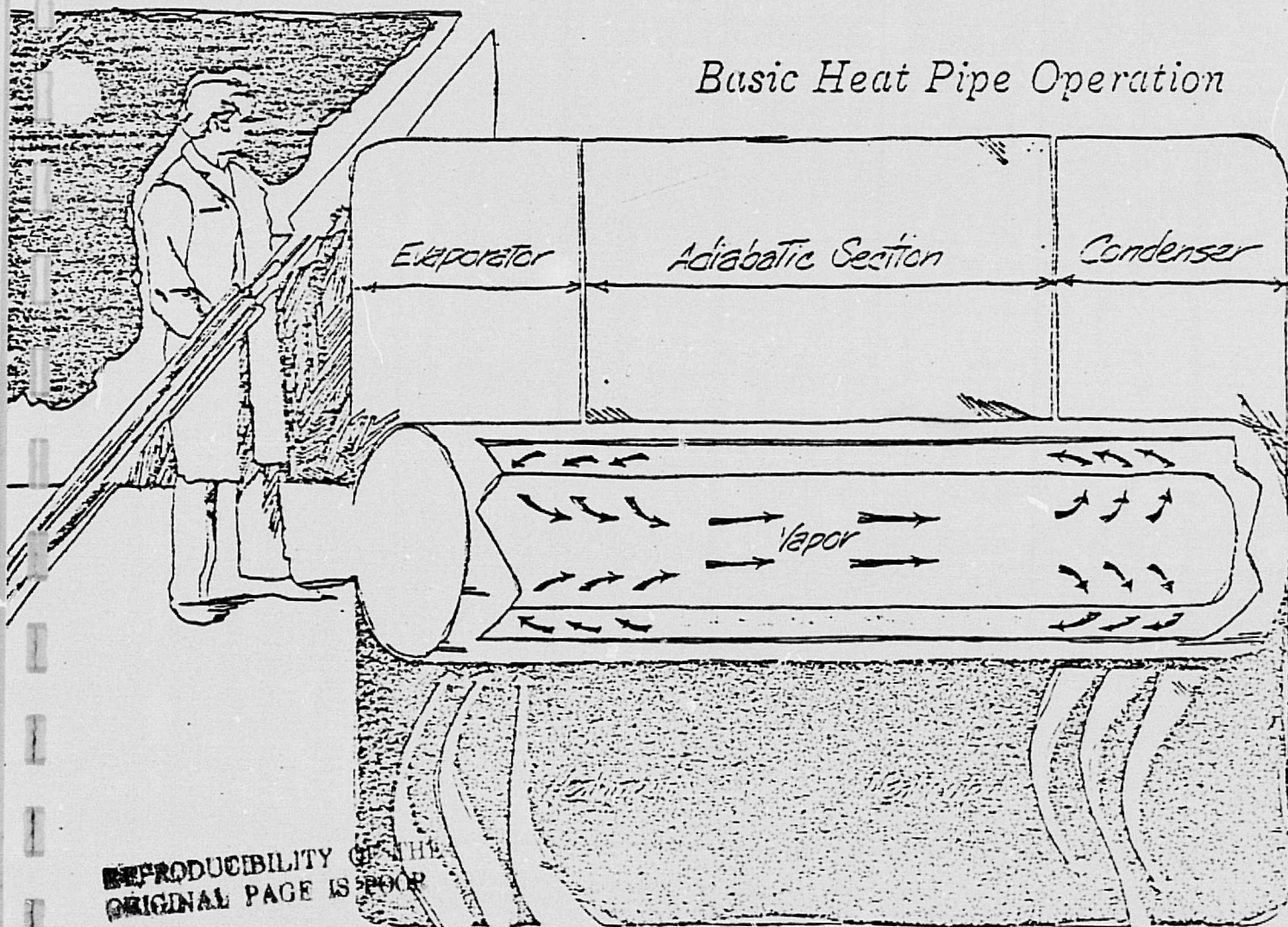
Protecting the tundra environment by keeping the permafrost frozen obviously was a significant consideration in passing of the pipeline bill in Congress.

The heat pipe was adapted to the Alaskan permafrost problem by McDonnell Douglas Corp. It is a sealed tube containing anhydrous ammonia, which has a boiling point of 25 F. The ammonia evaporates as it soaks up heat from the 30-degree permafrost. The heated gas rises to the top of the pipe and dissipates the heat through a fin-type radiator.

Having condensed back to a liquid, the anhydrous ammonia returns to the bottom of the pipe and the cycle repeats itself continuously, never allowing heat above 25 F to penetrate the permafrost. Thus heat pipes are totally automatic. They sense and respond to climatic conditions with no moving parts, require no external power, and never need adjustment or servicing.

The heat pipes are between 2 and 3 inches in diameter and 31 to 66 feet long, varying with the terrain. McDonnell Douglas-Tulsa is constructing

Basic Heat Pipe Operation



them for Alyeska Pipeline Service Co., the consortium responsible for construction and operation of the entire line.

McDonnell is building 112,000 of the heat pipes and radiators, an assembly it aptly calls a "cryo-anchor."

NASA's role in the Alaskan development did not end with initial research into reliable heat pipes for cooling spacecraft components. When Alyeska first became interested in heat pipes as a solution to the tundra problem, the Marshall Space Flight Center turned over the results of NASA research and channeled the consortium to NASA heat-pipe contractor companies.

Alyeska personnel also participated in a heat-pipe technology short course conducted by the NASA Industrial Applications Center at the University of New Mexico. And, as Alyeska's permafrost program neared completion, a technical review team at Goddard reviewed the heat-pipe application and suggested design improvements.

By developing the basic heat-pipe technology for space missions—and subsequently making that technology available to industry—NASA freed Alyeska from more costly, and longer-term, solutions. Thus, space research contributed directly to developing the North Slope energy resource.

Reclaiming waste heat

The heat pipe is probably the most efficient heat-transfer device known today. It can transport roughly 500 times the heat flux of the best solid conductors with a temperature drop of less than 3 degrees per foot.

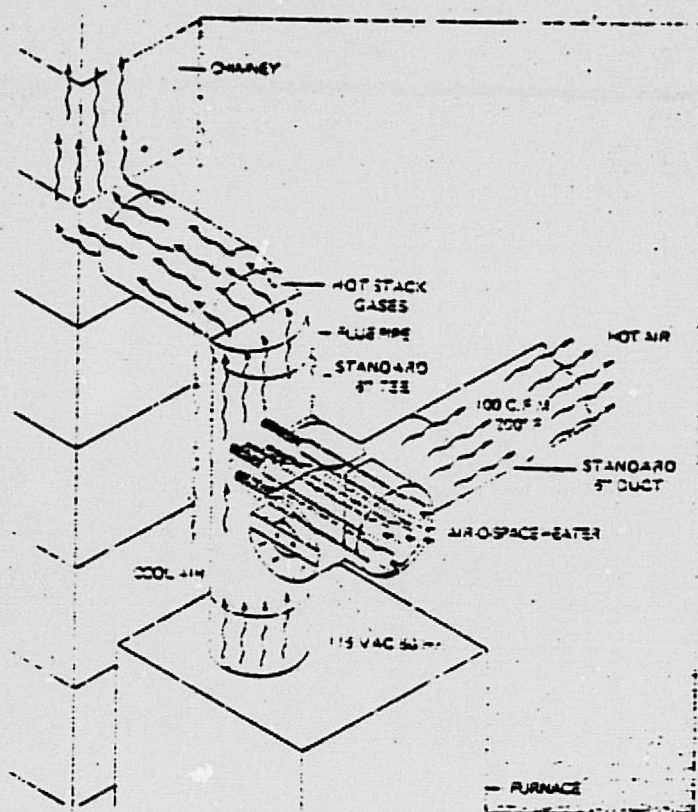
These facts led to the formation of Isothermics Inc., Augusta, N.J., to manufacture heat-pipe products. The equipment reclaims heat from chimney flue gases in home and industrial heating systems.

The heat pipes extend into the flue, pick up a portion of the heat and redirect it to the area to be heated. In home use a small fan draws surrounding air typically from the basement and forces it over the finned heat pipe. This heats the air, which then can be channeled for use in other areas.

A similar device uses the waste heat from industrial processes. It derives heat from the exhaust of a boiler or drier and returns it to the process or to a space heater.

These heaters are simple and inexpensive to install, requiring little modification other than additional ductwork to the existing system. In either home or industrial use, the only expense entailed in operating the heater is a small amount of electricity to power the fan. No additional fuel is required since the heat normally wasted is simply reused.

Isothermics has found that heat-pipe equipment increases efficiency in homes by about 10% and even more in industrial processes where waste-heat temperatures are higher. The heat-recovery devices



"Air-O-Space" heater based on spacecraft heat pipes requires no fuel other than electricity to run the fan. Installed in a chimney flue, heat pipes transfer the heat from waste hot gases (but not the gases themselves) to fresh air blown across the other end of the pipes.

actually pay for themselves in a few years.

The company is a subscriber to NASA's Industrial Applications Center at the University of New Mexico, where its employees attend symposiums on heat-pipe technology.

Another company, Kin-Tek Laboratories Inc., Texas City, has adapted NASA heat-pipe ideas and data to produce an instrument to calibrate gas analyzers used for air-pollution monitoring.

Flatplate solar energy collector

The avenues of technology transfer are illimitable. D. W. Barlow, a small truck-body fabricator in Florida became a producer of flatplate solar collectors after having an inexpensive literature search performed for him by a NASA information center.

The NASA Industrial Applications Center at the Research Triangle, N.C., searched its extensive technical literature files—containing both NASA and non-NASA reports—and provided Barlow with abstracts of 314 papers. Of these he requested 15 full-length articles.

His total cost: \$100. Yet it was sufficient to launch him into a new venture, O.E.M. Products Inc. His flatplate collector design incorporates a new black paint developed by Dow-Corning Corp., but not yet commercially available.

Ordering at a low ebb

With the financial condition of certain airlines shaky, inflation driving the cost of aircraft to unprecedented heights, the regulatory future uncertain, and the long-term availability of fuel a question mark, the airline industry has become extremely cautious in the ordering of new aircraft. At the end of 1975, five of the trunklines had no planes on order, a situation unprecedented in the three decades since World War II, a period of almost continuous re-equipment for the industry. As 1976 began, the trunklines had orders on the books for 80 aircraft, compared with 135 a year earlier. And, in view of prevailing conditions, it is inevitable that a further runoff of orders will continue through 1976.

The 1960s was the period of jet expansion, encompassing the original four-engine, long-haul models, followed by the development of the two- and three-engine medium and short-haul types (727s, 737s, DC-9s). The 1960s closed with the appearance of the larger capacity, stretch models of these older aircraft.

This series of aircraft was the most important element in the dynamic growth of the industry. The economies available through their operation greatly increased the productivity of the industry and made possible an extended period without fare increases, accompanied by a steady decline in yield as the benefits were passed along to customers through various discount fare programs. In 1960-69, the average operating cost per available ton-mile of capacity declined 30%, almost entirely reflecting the economies of the jet fleet.

The 1970s brought the introduction of the wide-bodied jets—the 747, the DC-10, and the L-1011. The substantial increase in seating capacity of these planes—as many as 450 seats in the 747 and up to 240-340 in the others—brought expectations of further substantial reductions in unit costs. To a large degree, these prospects have failed to be fulfilled. Although in some cases the wide-bodies have proved economical, the crippling inflation of the recent years has negated much of the cost efficiencies. On all but the densest long-haul routes, the 747 has not consistently produced the load factors necessary to permit profitable use.

As a result, ordering of wide-bodies for passenger routes has all but ceased. The financial crisis that hit the industry in the past two years has prompted several companies to pare down their wide-bodied fleet through the sale of 18 747s and several L-1011s. On the other hand, the value of the 747 as a cargo plane is just beginning to be appreciated, and there have been some new orders for this purpose, as well as the conversion of several from passenger to cargo configuration. It is the opinion of some officials of the aerospace industry that

total wide-bodied passenger capacity is about five years ahead of the level of traffic necessary to absorb it.

At September 30, 1975, there were 1,714 aircraft in the fleets of the trunk carriers. By type, these were 99 B-747s, 120 DC-10s, 63 L-1011s, 150 DC-8s, 273 B-707s, 23 B-720s, 741 B-727s, 83 B-737s, and 157 DC-9s.

Fleet efficiencies emphasized

The policy of fleet consolidation and streamlining has been the focus of airline planning for the past few years. The trend has been to fewer types of planes within the fleet, with heavy usage of the 727, which has proved to be the most efficient for a variety of different routes of any plane in airline history. Many older planes—approximately 100 in all—have been grounded and many sold in attempts to improve over-all fuel efficiency. Concentration on fewer types has reduced maintenance and training costs, made possible smaller parts inventories, and enhanced scheduling flexibility.

The current buying hiatus cannot be continued for too long in the view of most airline officials. There will be a need to replace older, smaller planes in the early 1980s, and planning for replacement models must begin soon. It is likely that the greatest need will be for a medium- to long-range type with a capacity of about 180-200. One possibility, the 727-300, an elongated version of the present 727-200, was abandoned in the fall of 1975, when orders were not forthcoming. The two proposals with the best chance of being developed are the BOEING 7X7 and the MCDONNELL DOUGLAS DC-X-200, both of which meet the above specifications. The possibilities that production of either of these will get under way in 1976, however, are slight.

To tide them over the growth expected in the next few years, the industry is looking to denser seating and increased utilization, which can provide the equivalent of a substantial number of additions to a fleet. For example, in early 1976, the trunks had programs completed or under way that would reduce the number of first-class seats by 6,700 and increase the number of coach seats by 12,000, for an over-all increase of 5,300. This would be equal to the addition of 40 B-727-200s.

Airport facilities strained

Although the growth rates expected have been scaled back from the enthusiastic projections of earlier years, it is still likely that the number of passengers using airport facilities will grow considerably in the next 10 years, placing a strain on existing facilities. Upgrading,

INTRODUCTION

This paper discusses the importance of aeronautics to the Nation, problems facing aeronautics which require research and technology solutions, and the role of the government in contributing to those solutions. The significance of the NASA aeronautics program in maintaining U.S. leadership in aeronautics is highlighted.

AERONAUTICS -- A NATIONAL RESOURCE

TRANSPORTATION SERVICE

Air transportation has grown rapidly in national importance during its relatively brief history. In the 1950's and 1960's (Figure 1) it emerged clearly as the dominant mode of public passenger travel in the U.S. A reduced but continued growth is expected through the years 1980-2000. Conservative estimates for this period suggest an average revenue passenger mile annual growth on the order of 5%. At this rate, air transportation demand would increase three- to four-fold by the end of the century, or by a factor of two during the later 1980's. (FAA projections show a growth in air revenue-passenger-miles to 360 billion by 1985.)

With business trips constituting approximately 50% of the public air travel, it is apparent that air transportation has become a vital element of the country's commerce and economy. This public mode is substantially augmented by general aviation activities. In addition to the 200 million passengers boarded annually by commercial aviation, general aviation carries 90 million. Of all general aviation operations 72% are for business or commercial purposes, and it is mainly through general aviation that the network of 12,200 airports beyond the 500 major facilities are served.

At present, air cargo lags considerably behind passenger travel in overall economic significance; cargo movement by air currently accounts for less than 1% of total intercity cargo movement. However, air cargo is growing at a considerably faster rate than passenger travel, and is expected to be an increasingly important factor in the nation's commerce in the future.

RELIANCE ON SPACE

COMMUNICATIONS INDUSTRY
REVOLUTIONIZED BY SPACE

National Aeronautics and
Space Administration

Washington, D.C.
20546

Reply to Attn of:

ECF

May 11, 1976

MEMORANDUM

TO: RX/Mr. Jerry Mullen

FROM: ECF/Mr. Samuel Fordyce

SUBJECT: Request for Information for Meeting with Dr. Fletcher

In 1965 there were 3,000 equivalent voice circuits in use for inter-regional communications. Approximately 3% of these were via the newly-launched INTELSAT I (Early Bird). Ten years later, this traffic has grown almost by a factor of ten. The satellites' share has increased to approximately 25%, and is growing at a faster rate than that of the submarine cables. It should be noted, however, that the competition from the satellites has spurred the technical development of the cables. The consumer has benefited from these advances, for the toll charges have decreased to less than half of their rates in these ten years.


Manager, Special Communications
Applications

ellites maintain a 24-hour watch on most of the Western Hemisphere, transmitting data to produce a picture every 30 minutes.

Improved communications through satellites have enabled ships and airplanes to find faster, safer routings around storms, ice, and other obstacles. Communications satellites have widened television coverage, extended education and medical care to remote regions, and even have reduced the cost of overseas phone calls.

The Intelsat, or International Telecommunications Satellite System, continues to grow in capability. This organization of 91 nations has brought the advantages of telecommunications to most of the world. The system today consists of more than 6,000 telephone circuits among 110 earth-station antennas located in 66 countries, and it is growing with new launches of improved satellites each year.

Larger applications technology satellites, powerful enough to broadcast directly from orbit into countless television sets, are being placed in geosynchronous orbit so that they'll hover, in effect, over a fixed spot on earth. The latest, the ATS-6, was launched in May 1974 and has performed flawlessly since. It has enabled physicians to conduct medical consultations in remote areas and brought high school and college courses to students in isolated Appalachian and Alaskan communities.

Dr. Wernher von Braun, president of the National Space Institute and vice president of Fairchild Industries Inc., which built the satellite, describes a typical scene. A seven-year old girl in a remote Alaskan village of 425 people had caught her hand in the wringer of an old-fashioned washing machine.

A doctor at a hospital in Tanana, several hundred miles distant, flipped a few switches and the badly frightened little girl appeared on the screen.

"Hold up your sore hand," the doctor said. "Now hold up your other hand and let me see if you can wiggle your thumbs."

Both could see each other. The isolated girl no longer was isolated. Not only could the doctor allay the girl's fear, but he could diagnose and treat her almost as well as if they were in the same room. He prescribed to the native nurse how to clean, bandage, and resplint the broken thumb.

Last May, a year after its launch, the 1.5-ton satellite was moved 8,000 miles to serve the people of India. Here, where a great many of the half-billion population live in villages and rural areas and almost none has ever seen a TV set, educational and medical telecasting may be the only realistic answer to improving the lives of an eighth of the people on earth.

The Indian government now has begun using ATS-6 to beam instructional television programs to some 5,000 villages and cities in seven states. India views satellite education as the only means to break the back of its widespread illiteracy.

Our lunar legacy

Both satellites and men have special roles in exploring the other worlds of our solar system. Where it is feasible for man to go, it is difficult to conceive of an instrument more capable. The human body has been defined as "a 10-cycle closed-loop, sensing, computing, and performance system in a 0.1-ton chassis with a 0.1-horsepower motor." Only such "equipment" could grasp the significance—and the adventure—of the moon's many complex phenomena.

When Neil Armstrong and Buzz Aldrin landed in the Sea of Tranquility the morning of July 20, 1969, about 1.5-billion people—almost half the population of the earth—were able to watch it by satellite-relayed television. Never before (or since) had so many human minds been concentrated at the same time on one activity. Man's first expedition to another world had enormous psychological and philosophical impact. It was a symbol of both human aspirations and inter-dependency. When we see our planet televised from the moon, the fact that it is finite, beautiful, and a single object, instead of 145 distinct nations, becomes overpowering. It may be trite to say, but true, that if spaceship earth sinks we all sink with it.

A second, even greater result of the expeditions to the moon was its prominent role in the beginning of a vast scientific awakening. Like all scientific endeavors, the practical benefit to us in our homes and lives will occur in the future. But we already have learned more about the moon and the origin and evolution of the earth through the six manned lunar missions than has been learned since the dawn of history. This abundance of scientific understanding, supplemented by robot probes to the planets, is rapidly advancing the earth sciences through a new field of comparative "planetology." With the world running out of oil and other minerals, the new knowledge couldn't come at a better time.

A third part of our lunar legacy reflects the primary intention of the Apollo flights. They were first steps, "travel engineering" missions, if you will, carried out to design and improve the equipment, to learn how to travel to the moon and back safely, to conduct what were essentially interplanetary expeditions—in short, to build a manned space capability.

To expect more than that psychological impact, more than that bountiful scientific harvest, and more than that engineering capability would be as though we lived at the end of the 15th Century and complained that Columbus failed to return sufficient quantities of gold from his first trips. No one dreamed of limiting future voyages then.

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WEATHER AND CLIMATE SERVICES
RELY ON SATELLITES

exploring the solar system

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The exploration of the solar system began with observations from space of our own planet. It started 19 years ago shortly after Sputnik roared its way into the consciousness of people throughout the world. Since then thousands of satellites built by dozens of countries have been launched, with the U.S. maintaining space leadership by a wide margin.

It's not who's first that counts, as Columbus proved. It's who's first with a difference. The fact that Soviets were first with a satellite or that we landed men first on the moon is of little relative importance.

The difference is that we landed men six times, returning human observations that will keep scientists busy for years, and that our satellites now assist in solving a multitude of world problems. We have built a space capability and have begun the exploration of the solar system, opening a new era of civilization.

Servants in space

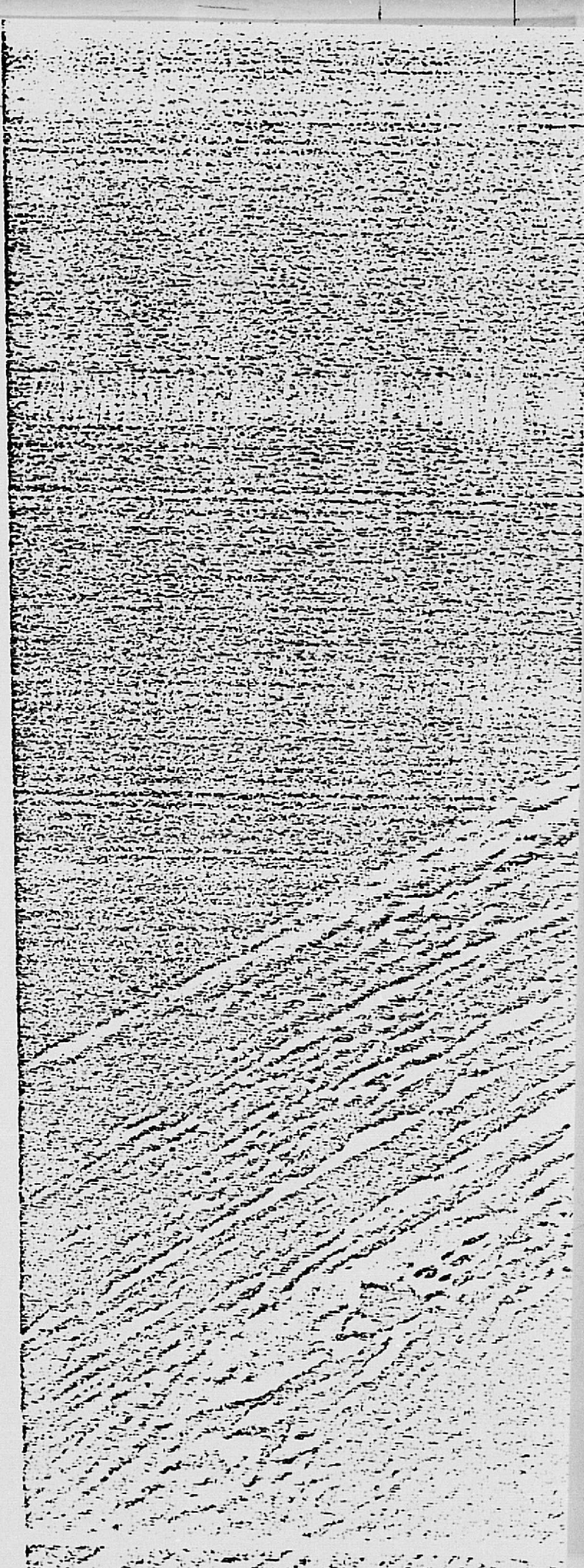
If outerspace exploration represents knowledge for tomorrow, the earth satellites are the workhorse machines of today. At the beginning of 1976 there was a swarm of about 750 satellites operating in earth orbit, 375 of them launched by the United States.

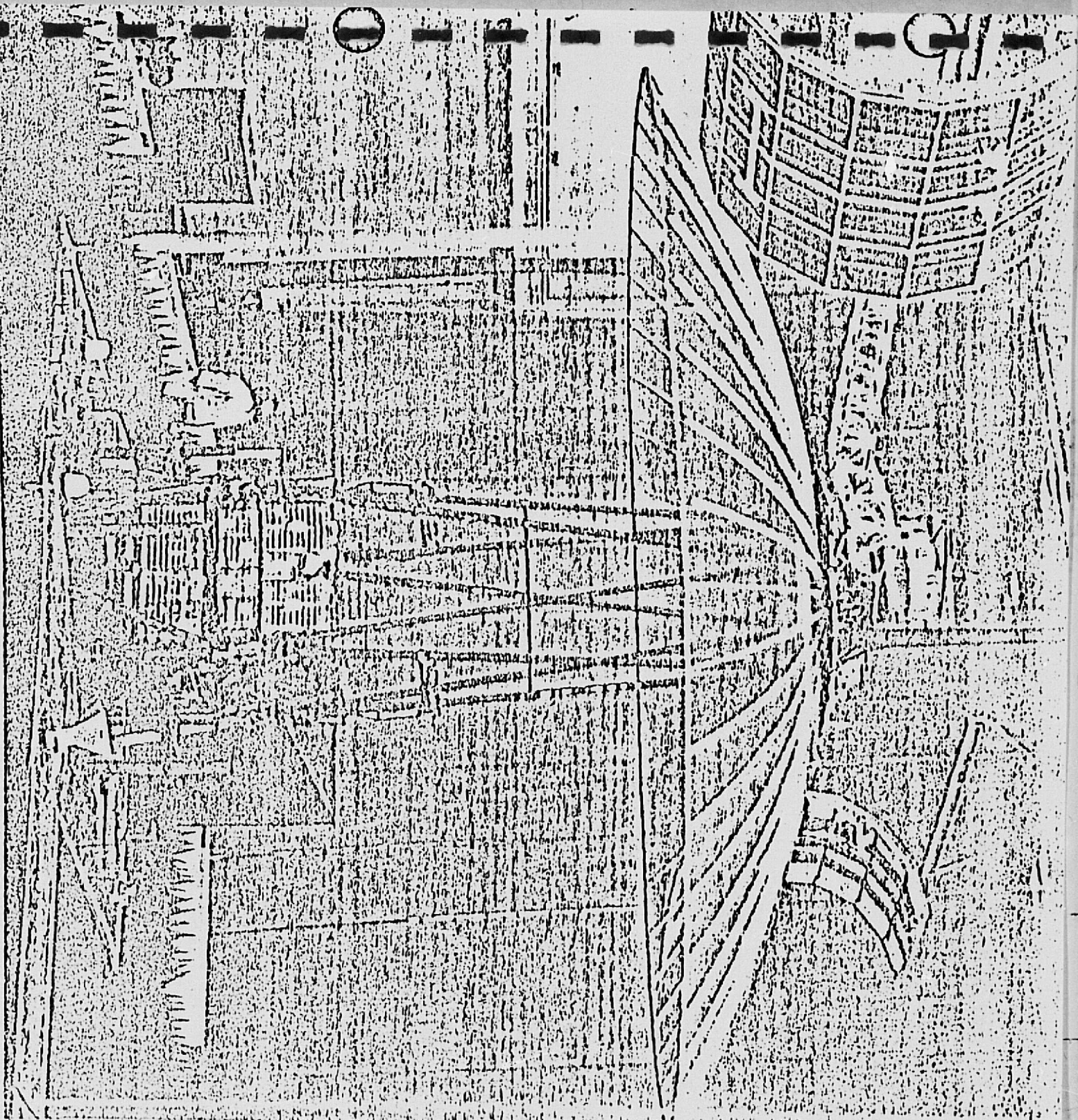
Among the many uses of these servants in space are weather forecasting, communications, scientific data gathering, solar observation, and prospecting and management of natural resources.

Good weather forecasting saves money. An accurate five-day forecast, which may be possible as satellite technology progresses, has been estimated to save up to \$5.5-billion yearly in the U.S. alone, and as much as \$15-billion for the entire world. The savings would be in agriculture, construction, transportation, recreation, and other industries.

Today's satellite system of weather watchers provides pictures of cloud cover over the globe both day and night. It contributes significantly to accuracy

First virtually continuous day-night photographs of a hurricane in the making were taken in 1974 by meteorological satellite in fixed orbit. Satellites are helping unravel how hurricanes and tornadoes form as first step in their possible control. Dramatic photo is hurricane Gladys stalled near Naples, Fla. in 1968. A vigorous updraft hid the storm's eye by flattening cloudtops against cold stable air of the tropopause and forming a wall of cumulonimbus 10 miles wide.





of one and two-day weather forecasts and increases man's ability to discover and track hurricanes, thus helping save lives and property.

The tropics are believed to be a key to earth's weather. Beginning in 1974, the United States and 69 other nations monitored virtually every known weather factor along a 20-million-square-mile rim of tropical land and sea around the world. Some 4,000 people using 41 ships, 40 buoys, 12 aircraft, five U.S. satellites, and one Soviet satellite probed from a mile below the sea surface to the top of the atmosphere. From stationary orbit, our synchronous weather sat-

The versatile Applications Technology Satellite (ATS), which now hovers 22,300 miles above the equator in fixed position relative to earth, shows its 30-ft parabolic mesh antenna. The satellite takes as long to orbit as it takes the earth to rotate on its axis—a "synchronous orbit." For the first time, with ATS-6, enough radiating power and beaming capability have been packed into a satellite to broadcast directly from orbit into TV sets in rural communities.

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IMPORTANT MILITARY APPLICATIONS

AN INSTRUMENT OF
INTERNATIONAL POLICY

The spinoff stimulus

Not only have men climbed the lunar craters. Not only have robot spaceships measured other planets. Most space benefits accrue directly to us on our own planet.

Today we educate the world via communications satellites. We prospect for oil with land-resource satellites. We keep the tundra frozen with spacecraft-derived heat pipes, making the Alaskan pipeline possible. Our damaged hearts are run by pacemakers, our ailments diagnosed by computer. Highways are grooved to prevent skidding. Bridges soon may be protected from corrosion. Better lubricants, more powerful solar cells, more efficiently designed railroad cars have been spun from space technology. Thousands of technical innovations are the payoff after 18 years in space.

Examples of how our national investment in space research and technology pays off will be described here, first as social, political, and economic stimuli and then in the exploration of space for its own purposes. The "research payoff" continues with current cases of space spinoffs that affect your job, your health, your mobility, your home, your environment, and your future.

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Technology: currency of foreign affairs

Few human undertakings in the modern world are so important as the development of technology. And yet few subjects are so little understood. When you think of technology you think of machines. But it should be emphasized that technology, or the practical utilization of science, today is applied outside of industrial life too. Consider, as a start, how space technology has been spun off to improve our relationships with other countries.

Technology—of which the space program has become a leading generator—is now a currency of foreign affairs. It is a tool of advanced nations and a hope for underdeveloped ones. The National Aeronautics & Space Administration has helped at least 75 countries by exchanging technical information, launching their satellites, sharing communications and data derived from our own satellites, and conducting foreign experiments on our spacecraft.

Pace setters in a free society

A free society needs pace setters in multiple activities. The alternative is mediocrity. No other technological endeavor has set—and met—as high standards as are required in the space program. The term "zero defects" is an invention of space technology in which machines must function perfectly in the almost impossible environments of vacuum and temperature extremes.

And yet all that represents just some of the indirect benefits of space technology. Space has its own purposes, targets, and destiny. Space technology already is accomplishing things that cannot otherwise be done economically, or perhaps done at all. This is happening in satellite monitoring of the weather, global communications, navigation, oceanography, meteorology, geology, astronomy, and of course exploration of the solar system.

Dollar returns from our tax penny

If you ask the man in the street how much the space program costs the country, his guess is likely to be \$20-billion a year. That's the figure he's heard and it sticks in his mind. That amount was the cost of nine years of the program to land men on the moon before the end of the decade of the sixties. As such, it was the primary cost of building our spaceport, tracking stations, and overall space capability.

It is a remarkable, often-overlooked fact that the pursuit of space goals generates innovations in virtu-

*Whatever stimulates massive scientific
will benefit all science, for what science most
can command the attention, respect*

ECONOMICS OF SPACE

NASA PROGRAMS EMPLOY
OVER 100,000 IN INDUSTRY

NASA SPENDING IMMEDIATELY CREATES PRODUCTIVE JOBS

There are several aspects of NASA expenditures that make them a relatively effective short term mechanism in reducing unemployment, and accomplishing this reduction in a non-inflationary way. These are summarized in Chart 1:

- o NASA expenditures are labor intensive. About 85 percent of NASA spending goes directly to productive jobs and 15 percent goes for materials.
- o NASA expenditures are non-inflationary. There is significant unemployment, underemployment, and unused capacity in the aerospace industry, and increased NASA expenditures would not lead to labor shortages, or capacity bottlenecks with their attendant price increases. Furthermore, there would be no lag in putting people and machines to work.
- o Every \$100 million of NASA spending is equivalent of about 4,000 direct jobs per year.
- o The short-term demand multiplier effect of additional jobs created indirectly in the community and the economy at large is significant and brings the total number of jobs resulting from each \$100 million of NASA expenditure to as many as 10,000 jobs.

At 10,000 employees per \$100 million of expenditures, NASA is near the top of the list of Federal expenditures in terms of short-run employment generation. These figures are based on contractor data and econometric estimates of the employment impact of the aerospace industry on the California economy. Moreover, these figures are corroborated by preliminary results of the Chase Econometric Associates' study, The Economic Impact of NASA R&D (forthcoming), which considers the short-term impact of NASA expenditures within the context of the Chase Econometric model of the U.S. economy, as well as the long-term productivity effects quoted above.

NASA TECHNOLOGY PAYS HUGE DIVIDENDS

○ MORGENSTERN STUDY

- GAS TURBINES IN ELECTRIC POWER GENERATION
- INTEGRATED CIRCUITS IN CONSUMER PRODUCTS
- SPACE-DERIVED INSULATION FOR CRYOGENICS
- COMPUTERIZED STRUCTURAL ANALYSIS

\$7 BILLION
IN BENEFITS

○ CHASE ECONOMETRICS STUDY

- EACH DOLLAR INVESTED RETURNS \$14 TO THE ECONOMY OVER A 10-YEAR PERIOD THROUGH PRODUCTIVITY
- A \$500M SUSTAINED INCREASE IN NASA R&D, COMMENCING IN 1975,
 - LOWERS CONSUMER PRICE INDEX BY 1% BY 1984
 - LOWERS UNEMPLOYMENT BY .2% BY 1984
 - INCREASES 1984 EMPLOYMENT BY 400,000 WORKERS
 - INCREASES REAL GNP BY \$11.3 BILLION
 - YIELDS 38% RETURN ON INVESTMENT IN 10 YEARS
 - AND FURTHERS NATIONAL OBJECTIVES IN SPACE AND AERONAUTICS

WHOLE NEW INDUSTRIES
HAVE BEEN CREATED

NASA TECHNOLOGY PAYS HUGE DIVIDENDS

The economic impact of NASA's R&D expenditures and those of similar high-technology programs is to increase productivity both through direct applications of aerospace technology (e.g., communication satellites, improved aircraft, etc.) and indirectly (but significantly) through the development and dissemination of advanced technology which is then applied in many other sectors of the economy. Indirect applications may be in "new" products and services (e.g. miniaturized calculators, heart pacemakers, video tape storage and retrieval systems, etc.) or in lower production costs for existing products and services (e.g., integrated circuits for electronic equipment in products and processes, gas turbines, etc.).

Chart 4 summarizes the results of two major studies that have been undertaken to quantify and document the productivity impacts of NASA R&D expenditures. A study by Mathematica, Inc., the "Morgenstern Study," summarized in the upper half of the chart, estimated the contribution of NASA R&D to four major technological improvements -- gas turbines, integrated circuits, cryogenic insulation, and computerized structural analysis. The benefits resulting from NASA's work in these four technologies were estimated to be in the neighborhood of \$7 billion. Because the Mathematica study only considered a selected group of spinoffs, further analysis was undertaken by Chase Econometric Associates, Inc., to ascertain the total spinoff impact from NASA technology. The Chase study statistically quantified the contribution of NASA R&D expenditures to productivity growth rates of the national economy. Key results of this study are presented in the lower half of Chart 4. The highly beneficial impact of NASA R&D found in this study results from the large impact Chase estimates that NASA R&D has on productivity growth. As shown in the chart, there is, over a 10-year period, a gain of \$14 in additional productive capacity (real GNP) for each \$1 of additional NASA R&D spending. Equally important are the effects of productivity growth increases on employment and inflation. As productivity growth increases and the economy expands at a faster pace, demand for labor increases and more workers find jobs. Here Chase estimates that a sustained real increase of \$500 million (1958 dollars) in NASA R&D beginning in 1975 and continuing through 1984 will, by 1984, generate 400,000 more jobs.

The same sustained increase in NASA R&D also reduces the rate of consumer price increases. This is the case because, for every 1 percent increase in productivity growth, wages can be advanced by 1 percent without placing any upward pressures on production costs and product prices.

TRENDS

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TRENDS

U. S. LACKS OR LAGS

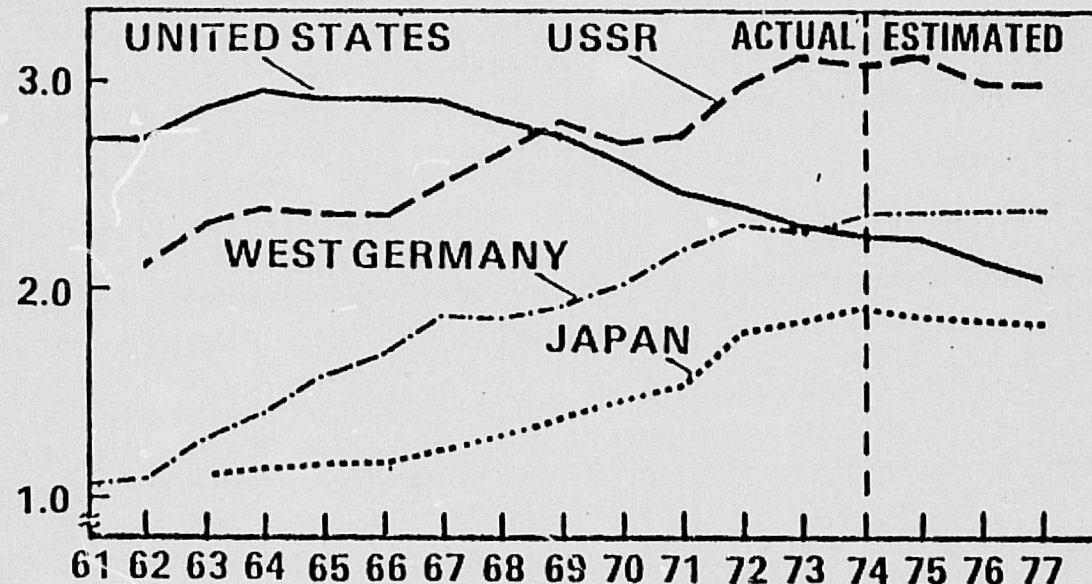
- CRITICAL RAW MATERIALS
- SUPERCONDUCTING SYSTEMS
- MHD POWER GENERATION
- SUPERSONIC TRANSPORTS
- HELICOPTERS

RECENT TECHNOLOGY IMPORTS

ELECTROSLAG PROCESS.....USSR
 MACHINE TOOLS.....EUROPE
 X-RAY SCANNER.....U. K.
 TURBO TRAINS.....FRANCE

TECHNOLOGY INVESTMENT POLICY

R & D AS % OF GNP



► U. S. RISKING LOSS OF TECHNOLOGICAL LEADERSHIP

LAGS/LACKS

• U.S. RAW MATERIAL DEPENDENCE

MATERIAL	ALUMINUM	NICKEL	TIN	ZINC	CHROMIUM	MANGANESE
% IMPORTED	86	72	87	63	91	98

- (2) • U.S. WORK IN SUPERCONDUCTIVITY HAS LAGGED BADLY FOR PAST 10 YEARS WHILE SOVIET WORK PROGRESSED UNIFORMLY AND HAS GREATER POTENTIAL FOR FUTURE ADVANCEMENT AND STUDY.
- (3) • USSR NOW OPERATING WORLD'S FIRST MHD POWER PLANT (5MW, 25MW PLANNED) U.S. BELIEVED 5 YEARS AWAY FROM CONSTRUCTION OF PILOT PLANT OF THIS TYPE. COMMERCIAL POTENTIAL CONSIDERABLE IN VIEW OF CURRENT ENERGY PROBLEMS.
- (4) • FRENCH AEROSPATIALE INTRODUCING AS350 IN DIRECT COMPETITION WITH BELL JET RINGER. COST EFFICIENT DESIGN STRESSES TECHNICAL INNOVATIONS. \$157 MILLION IN EXPORTS LAST YEAR COMPARED TO U.S. \$210M.

TECHNOLOGY IMPORTS

- (5) • SOVIET ELECTROSLAG CASTING PROCESS PRODUCES CASTINGS EQUAL TO FORGED PRODUCTS AND HAS GRANTED LICENSES TO FRANCE, SWEDEN, JAPAN, U.S. AND OTHERS.
- (6) • U.S. IMPORTED 15% OF ITS MACHINE TOOLS IN 1974, UP 300% SINCE 1965.
- (7) • BRITAIN'S EMI PIONEERING WORK IN DEVELOPING X-RAY WITH PROVEN VALUE IN PINPOINTING TUMORS AND VASCULAR LESIONS WITHOUT PAINFUL, DANGEROUS SURGERY HAS U.S. LEADERSHIP IN \$1.5 BILLION POTENTIAL MARKET.
- (8) • U.S. IMPORTING PASSENGER TRAIN TECHNOLOGY FOUND TO BE SUPERIOR IN MAINTENANCE AND RELIABILITY.

R&D INVESTMENT POLICY

- (9) • CONTINUATION OF CURRENT POLICIES COULD CAUSE A POTENTIAL \$100 BILLION LOSS IN GNP IN NEXT 10 YEARS. (HARVARD STUDY)
- (10) • STANDARD PROJECTIONS (ACADEMY OF SCIENCE) OF PHD PHYSICISTS LOW DUE TO NON-CONSIDERATION OF SALARY IMPACT OF R&D SPENDING CUTBACKS.

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Continued Defense Spending Rise Seen

By William H. Gregory

New York—Defense spending will continue to grow over the next 10 years with a prospective turnaround in public attitude toward military security, Stanford Research Institute economic and political studies are forecasting.

What appears to be an abrupt change this year in the congressional ax-wielding mood toward the Fiscal 1977 U.S. defense budget was not expected so soon by the research team.

It is forecasting further efforts to trim military funding, on the premise, posed by team member and political scientist Kenneth H. Jacobson, that Congress lags behind changes in voter sentiment by months, or perhaps years.

Timing of the growth in industry defense sales in the team's outlook puts bigger percentage gains toward the end of this decade in line with the congressional-lag premise that Defense Dept.'s long-term growth target for weapons procurement will not be reached much before 1980.

Forecast Elements

Other elements in the forecast by the Stanford Research team:

- Cash flow requirements for all types of companies to carry their defense business also will grow over the next 10 years, but they will have difficulty raising all the capital they need.

- Capital shortages may develop within five years.

- Defense spending is declining as a percentage of gross national product in most countries outside the Soviet bloc and will continue to decline. Iran, Israel and Saudi Arabia are exceptions.

- Global economic growth will be stronger in the second half of this decade than in the recession-scarred first half. To the extent that general economic growth encourages defense spending, the defense industry will show steadier growth through 1980.

- Competition for funds between defense and social needs, already strong, will intensify over the next decade.

Impending capital-raising problems, predicted by the team's industrial economist, David E. Raphael, are based on three grounds. Defense is a cyclical business, it is risky and at least some major companies, if not the industry as a whole, have had a poor track record. The last is a reference to profitability, whether measured as a return on sales, on investment or on total capital employed in the industry.

Aerospace companies historically have earned lower profit margins on sales than

manufacturers as a whole, but there had been an offset.

Government-built facilities meant a lower investment by stockholders and a higher return on equity than manufacturing in general as a result.

Over a 10-year period beginning in 1965, the relationship changed:

- In 1965, U.S. aerospace company profit margins on sales averaged 57% of that for all manufacturing, but return on equity capital was 116% and return on total investment was 97% of that for manufacturing as a whole.

- In 1974, average aerospace company margins on sales were 55% of all manufacturing, not a great deal of change. Average return on equity dropped to 71% of the total group, and return on total capital invested to 54%.

Total capital invested includes bank borrowings and other forms of short- or long-term debt.

Aerospace companies, like airlines, have tended to go the debt route to raise capital rather than sell stock to the public because of their heretofore strong cash flow positions.

Although the Stanford Research forecast is for a gradual growth in real defense spending, the team also simulated a U.S. defense buildup situation after

1980. Its probable growth forecast compared with the build-up forecast showed:

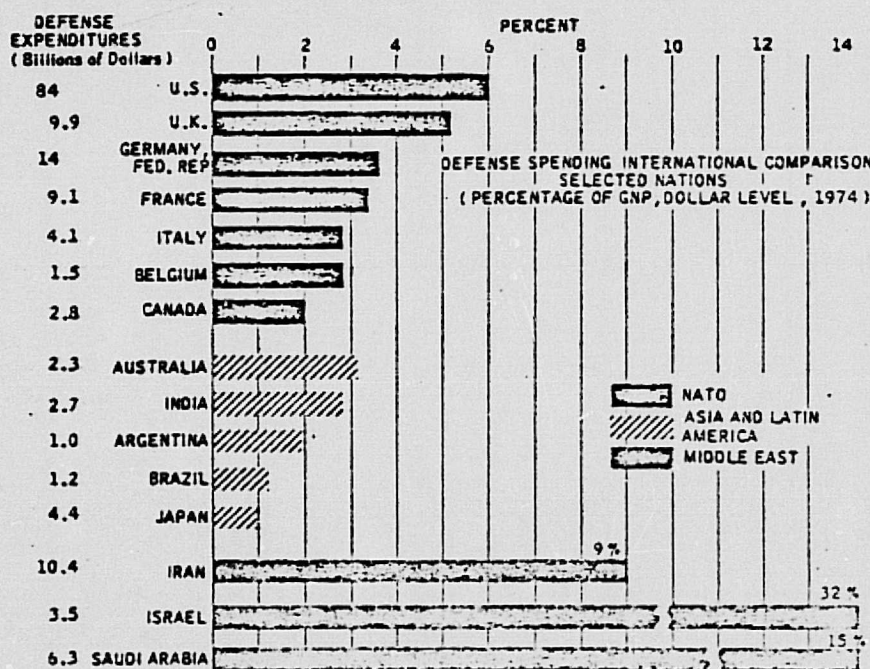
- Probable—Defense spending growing at an annual 2% rate in constant dollars from 1981-1985 and gross national product at a rate slightly over 3%.

- Buildup—Defense spending growing at a rate of about 5.6%, outpacing gross national product growth at close to 5.4%.

Some recent university and public-interest group studies, stemming from the tug-of-war between social welfare and defense for funding, have renewed the argument that defense spending depresses national employment, that it has a net negative impact on the economy by siphoning money from private hands that otherwise would have gone into non-defense production and consumption.

Opposite Conclusion

As the buildup growth rate in gross national product implies, the Stanford Research simulation reached the opposite conclusion. Its results, which included a matrix of defense sales of 30 U.S. industries either directly to the government or as subcontractors or suppliers to prime contractors, agreed with some other mathematical economic analyses that defense spending exerts positive pressure on the general economy. Raphael summa-



Defense expenditures of the U.S. as a percentage of gross national product are compared in Stanford Research Institute study with other nations in Europe, Asia and South America. Generally, percentages are declining, but the Middle East is an exception.

Paris—European Space Agency will establish a special technical management team to coordinate and integrate European payloads for the agency's first Spacelab flight in the U. S.-built space shuttle.

With a staff of approximately 20, the team will be responsible for such tasks as:

- Planning and coordinating instrument and experiment development, European payload integration centers and European participation in the joint NASA/ESA payload accommodation and launch teams.

- Data management.

- Preparation of design and interface specifications.

- Acceptance of experiments.

- Approval of integration-related tests.

- Monitoring payload-related schedules.

- Coordination of payload specialist training programs.

In conjunction with ESA's efforts to make maximum use of existing European facilities, the agency will locate the payload team at Germany's DFVLR technical center at Porz-Wahn.

About half the team will be drawn from the Porz-Wahn staff. The team will be headed by Max Hauzeur.

alized the study results by saying:

- Defense spending stimulates as many as or more payroll dollars in the U. S. economy, both military and civilian jobs, than non-defense spending does.

- Every dollar cut from the defense budget removes \$2 from the U. S. economy—\$1 in direct defense sales and \$1 in indirect sales to the defense supplier or his employee.

The Stanford study excluded transfer payments—primarily Social Security payments—from the non-defense side of the economy.

If these had been included, Raphael says, the non-defense side would generate even fewer payroll dollars than the defense budget dollar does when it is spread through the economy. In effect, the de-

fense dollar is a higher velocity dollar in the way it moves through the economy and the kind of buying it stimulates.

While aerospace industry sales in 1975—including commercial, avionics and other related equipment—were close to \$29 billion, the defense dollar looked at another way indicates the kind of turnover in the economy.

Direct or indirect defense sales of 30 U. S. industries investigated in the Stanford study amounted to \$50.8 billion. Total defense sales of all industries were \$68.6 billion.

These figures include double counting—sales from one industry to another that are included in the total price of the hardware delivered. They do give some indication of the stimulation and velocity

ertheless.

The study forecasts that:

- Total defense sales of all U. S. industries in 1980 will reach \$81.9 billion and \$91.1 billion in 1985—both figures in 1975 prices. This is a compounded annual real growth rate of 2.9%.

- Cash flow requirements for total defense business will rise to \$8.7 billion in 1980 and \$9.6 billion in 1985, similarly in 1975 prices. The 1975 figure was \$7.3 billion, and the estimated growth also is 2.9% compounded.

Results of the study have been discussed at Institute seminars, including one in New York.

The study was not done for any particular client, and is thus being furnished to all the Institute's clients.

Discussion at the New York meeting by industry participants reflected the rising concern over congressional checks on export sales, particularly in the wake of overseas payment disclosures.

Legal Problems

Besides the provisions of a proposed law that would require congressional approval of commercial as well as military sales overseas, there were comments about other potential legal entanglements—discrimination, for one.

If the U. S. attempts to apply its policies to eliminate discrimination against women in questions of approval of overseas sales, one participant said, Saudi Arabia might technically be eliminated as a U. S. customer.

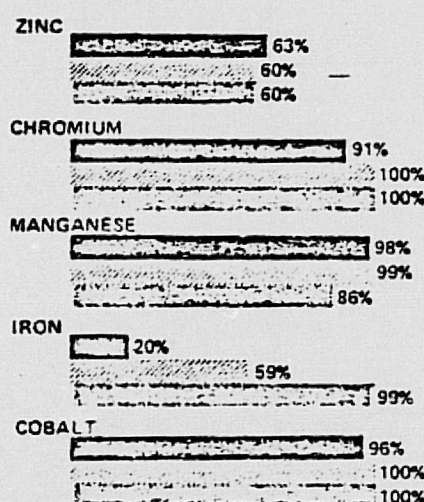
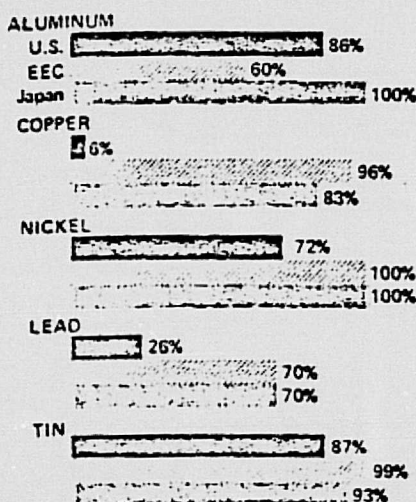
Another participant was concerned about what effects disclosure of the details of weapons sales to Congress will have on buyers overseas.

While the disclosures may seem normal or unimportant to the U. S., the buying nation may take a jaundiced view of revelation in Congress of what it regards as military secrets to the benefit of its neighbors.

Soviet Defense Budget

A third member of the team, David Benson, a systems analyst, discussed the Soviet defense budget versus that of the U. S. Although the relative budgets were compared in dollars, Benson commented that he did not believe in trying to measure the Soviet budget by that U. S. yardstick, except that there is no other way to do it. Although the Central Intelligence Agency estimates the Soviet defense effort is equivalent to 12-15% of Soviet gross national product—twice that of the U. S. proportion—Benson said the gap would be larger if personnel were excluded.

A significant part of the Soviet defense budget is represented in concentration of forces along the Chinese border, he said, but added: "Sophisticated fighter production is not likely to be directed toward China."



Raw material dependence of U. S. and its allies ranges for various metals, Stanford Research study shows. The study does not forecast a global mineral shortage of major proportions but substitutes could become more expensive. Aluminum is an example. As an element, it is ubiquitous, but commercial production at this point has relied on bauxite where natural weathering has concentrated aluminum for lower cost recovery. Recovery from hard rock could be costlier in terms of dollars and energy required.

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The major findings of this paper are:

1. Work in advanced concepts of superconductivity in the United States lagged badly for the major part of a decade (1964-1973), while that in the USSR progressed uniformly.
2. Within the last three years the United States has shown greater progress than the USSR.
3. Soviet HTS research is approximately on a par with our own, but has a greater potential for future advancement.
4. National policy on superconductivity exists in the USSR under unified leadership.
5. United States support of HTS research is more austere than Soviet.
6. Soviet HTS research is more organized and coordinated than American.
7. Soviet research staff population is more stable than America; institutional differences are held partly responsible for this.
8. American HTS research is conducted primarily by physicists; the Soviet approach tends to be interdisciplinary, involving physicists, chemists, materials scientists, etc.
9. Soviet research style is not generally conducive to rapid exploitation of its own theoretical and experimental results.
10. Soviet HTS studies are useful in assessment of developments and potential value.

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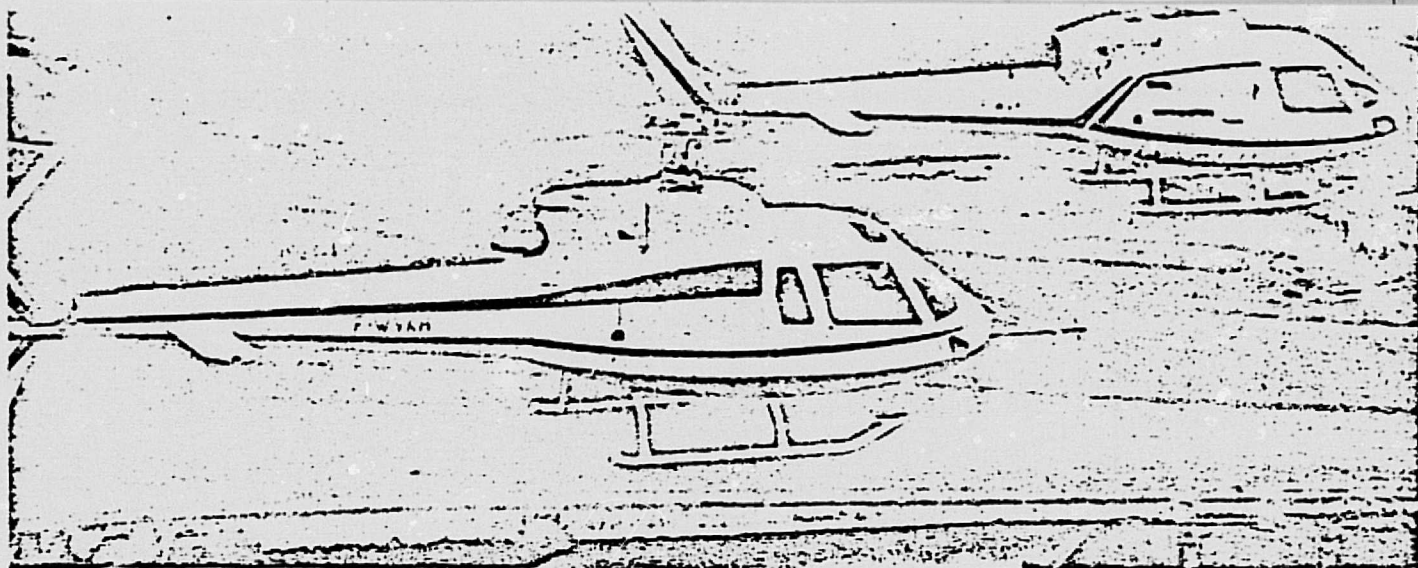
SUMMARY

The size and scope of the Soviet MHD-power generation program far exceeds that of the United States. The USSR is now operating the world's first MHD power plant, currently attaining 5 MW(e) of a 25-MW(e) planned power output. The Soviet closed-cycle MHD program appears to be small and lags that of the United States; the Soviet open-cycle effort (representing about 80 percent of their visible MHD research) leads that of the United States, which is believed to be about five years away from the construction of a pilot plant of the Soviet type. The USSR has considerable experience in integrated plant operation, while the United States, because of its early concentration on military applications, has a substantially advanced understanding of high-performance MHD-generator operation.

The commercial potential of open-cycle (and to a lesser extent, closed-cycle) MHD power generation is considerable, especially in view of current energy problems. Provided certain technological problems can be resolved, MHD offers the possibility of low-pollution electric-power plants of very simple construction (i.e., no moving parts) with considerably improved conversion efficiencies, using plentiful high-sulfur coal, at capital costs comparable to those of conventional turbine plants. A recently negotiated U.S.-Soviet agreement provides the possibility of coordinating the two approaches to the benefit of both countries.

The present Report, in successive sections, briefly reviews MHD technology, traces the evolution of the MHD programs in the United States and USSR and their respective development approaches, and compares major U.S. and USSR MHD facilities and national program objectives.

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Of the two AS-350 prototypes now flying, the first (foreground) flew for the first time in June, 1974, powered by a single 600-shp. Lycoming LTS101 turboshaft engine. Second aircraft, powered by a 650-shp. Turbomeca Arriel engine, made its first flight six months later.

Aeronautical Engineering

Civil Helicopter Competition Stiffens

By Robert R. Ropelewski

Marignane, France—Aerospatiale of France will begin deliveries of its new 5-6-place AS-350 helicopter in 1978 in direct competition with the Bell JetRanger in an expanding civil helicopter market (AW&ST Apr. 12, p. 20).

At the same time, officials of Aerospatiale's Helicopter Div. believe, the aircraft will find a strong market as a replacement for the more than 1,300 Alouette 2 four-place helicopters sold by the company. Production of the Alouette 2 came to a stop last year, and the AS-350 is seen as a low-cost replacement.

The AS-350 is the first new design to come out of Aerospatiale's Helicopter Div. since the nationally-owned company was formed in 1970 from several smaller French aeronautical firms. AS is the designator for Aerospatiale. The company's current line of helicopters all bear the designator SA, for Sud Aviation, which initiated all of the current French helicopter programs before it was incorporated into what is now Aerospatiale.

The aircraft has been named *Écureuil* (squirrel in French) for the French market and other markets outside the United States. But officials expect Aerospatiale Helicopter Corp. in the U. S. to give it another name there.

To hold down both initial price and operating costs, the French manufacturer is stressing a simplicity of design based on several new technical innovations, modest performance goals and use of off-the-shelf hardware—some of it coming from the automotive rather than the aeronautical sector.

Some of its main features include:

- Starflex rotor head, a patented Aerospatiale design with a three-armed epoxy-glass fiber hub to which yoke-shaped blade roots—replacing blade sleeves—are attached at elastomer laminate spherical thrust bearings (one for

each blade) around the center of the hub. The flexibility of the hub and the blade yokes, which are themselves made of glass fiber and resin, and the elastomeric thrust bearings allow for lead-lag, flapping and blade-pitch changes without the use of the heavy and complicated lubricated bearings found on standard articulated rotors. Aerospatiale engineers say weight of the AS-350's rotor head is about half that of an equivalent conventional articulated rotor head, and cost is about one-quarter to one-half that of a conventional head. In addition, simplicity of the new design allows operators to perform the limited maintenance required.

- Plastic rotor blades with unlimited fatigue life. The simplicity of the blade yoke attachment to the rotor hub allows the three blades to be changed by an operator in about 15 min. with no special tools. This was demonstrated here by Aerospatiale technicians between demonstration flights of the aircraft. No special adjustments were needed after the blade change, and total ground time for the entire operation was about 20 min.

- Off-the-shelf systems from French automotive manufacturers, and particularly oil coolers and fuel pumps. These items were adopted originally because

they were lighter, cheaper and less complex than similar items specially designed for aeronautical applications. Added bonus has been discovered, however, in that the automotive systems are providing higher performance than their aeronautical equivalents.

- Simplified main gear box has two reduction stages and a total of only nine gears and nine bearings. Maintenance will be on-condition, and a modular design will allow operators to change the modules themselves.

- Single turboshaft engine will power the AS-350, but two different engines are being tested and certificated on the aircraft. For aircraft produced and sold by Aerospatiale outside the North American market, the 650-shp. Turbomeca Arriel engine will be offered. For those assembled and sold in the North American market by Aerospatiale Helicopter Corp. (AHC) in the U. S., the 600-shp. Lycoming LTS101 will be used.

- Maximum gross weight of 4,190 lb., payload capability (not counting the pilot) of 1,940 lb., maximum sea level speed of 159 mph. (137 kt. or 256 km./hr.), sea level cruise speed of 143 mph. (124 kt. or 230 km./hr.), hover out-of-ground-effect ceiling of 6,560 ft. (2,000 meters) and a sea level range of 460 stat. mi. (740 km.).

Aerospatiale's helicopter engineers have been conducting a major effort for 10 years to simplify helicopter systems, and particularly rotor systems. Several developmental programs are currently under way here on new rotor head con-

cepts, and some of these are being flight tested on the company's SA-360 and SA-365 Dauphin, SA-341 Gazelle and SA-330 Puma helicopters.

The furthest advanced of these systems is the Starflex, and the company believes that Starflex development has proceeded far enough to qualify it for use on a production aircraft. The Starflex rotor head is probably the most significant innovation on the AS-350, particularly in terms of weight saving, low production costs and simplicity of maintenance.

There are few items to be inspected on the head. The elastomeric bearings can be checked and changed, when necessary, by the operator himself. Total number of pieces in the head is 64, compared to 377 on the SA-318, the latest model of the Alouette 2 series. The head weighs about 128 lb., which is around 45% less than that of the Alouette 2.

Major aim in designing the AS-350, Aerospatiale engineers say, was to keep production costs down by making the aircraft as simple as possible, reducing components to the smallest possible number, using modern materials and production methods and avoiding close tolerances and expensive materials and manufacturing processes.

Another aim was to hold operating costs down by producing an aircraft with components of long times-between-overhaul (TBO) and offering the possibility of accomplishing most maintenance work at the operator level.

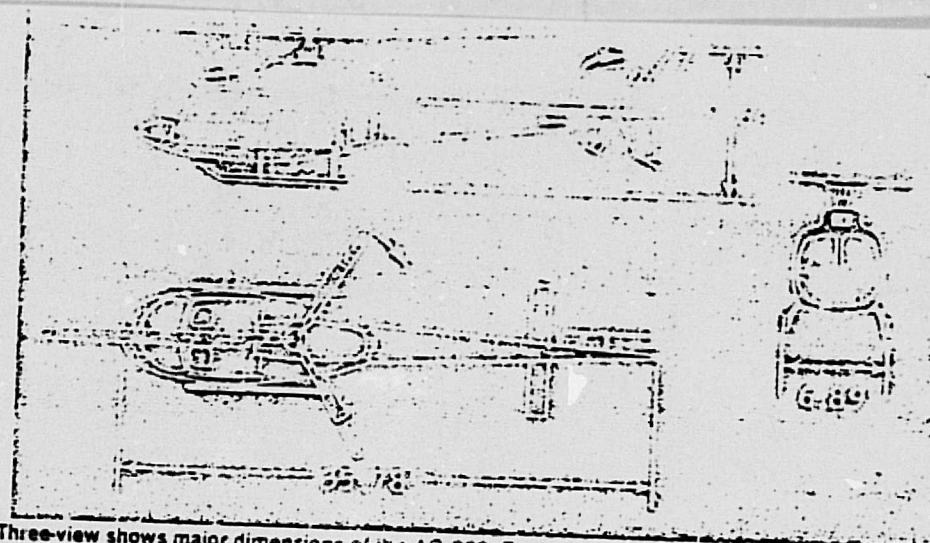
One example of the results of these goals is the main gearbox of the AS-350, which will have a production cost of 59% of that of the main gearbox on the Alouette 2, and an operating cost of only 21% of the Alouette 2 gearbox. Total operating cost of the AS-350, including crew, fuel and amortization, is expected to be only 63% of the operating cost of the Alouette 2.

Aerospatiale already has some experience to back up these figures, since the first AS-350 prototype made its maiden flight in secrecy almost two years ago, in June, 1974. That aircraft was powered by the Lycoming LTS101 engine. A second prototype flew about six months later, powered by the Turbomeca Arriel engine.

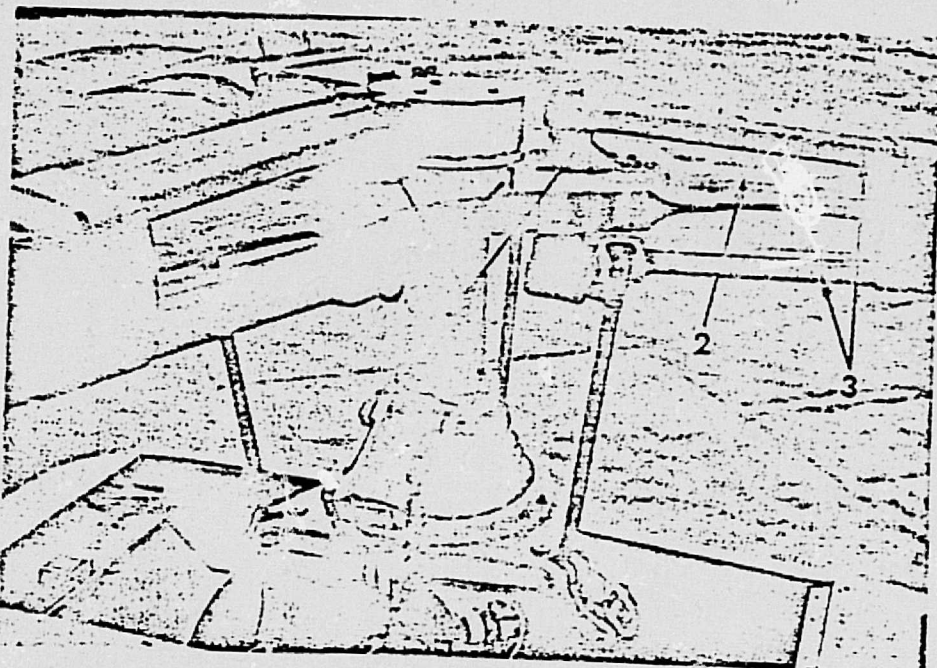
Helicopter Div. officials foresee a major expansion in the market for single-engine, five-place helicopters over the next 10 years, mostly in the civil sector. The company is estimating a total market for about 28,000 helicopters of all types over the next 10 years, about 15,000 of which will be in the military sector while the other 13,000 will go to the civil sector.

By percentage, the civil market is expected to be divided into:

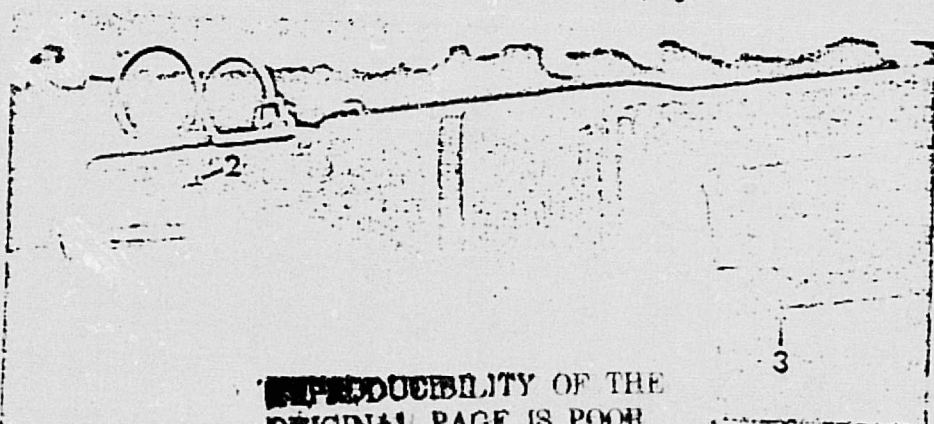
- Medium and heavy twin-engine—3%, or about 900 helicopters.
- Light twin engine—35%, or about 4,550 helicopters.
- Very light, single-engine two-three



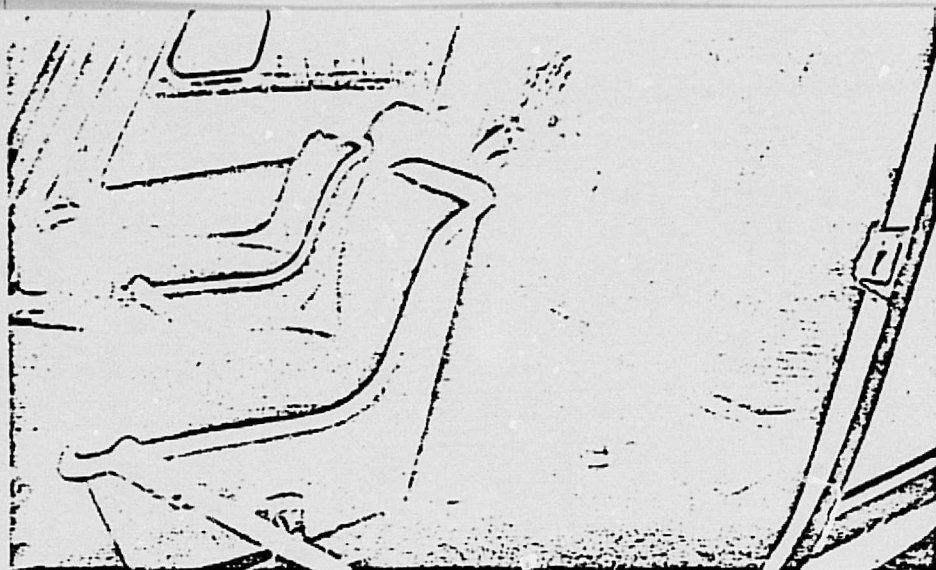
Three-view shows major dimensions of the AS-350. Rotor diameter is 35.06 ft.



Closeup of Starflex simplified rotor head (above) shows hub (1), hub arms (2), which are not attached to blades but which absorb blade droop loads when rotor is stopped, and composite glass fiber/resin blade sleeves/yokes (3) which connect blades to the hub at elastomer laminate spherical thrust bearings (4). Closeup (below) of sleeve shows plastic rotor blade (1) attached to sleeve/yoke (2). One of the three arms of the rotor hub itself is at right (3). The arms extend only as far as the glass fiber winding around the sleeve/yoke (4), and carry loads only when the rotor is stopped and blades are drooping.



REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR



Standard interior of AS-350 has five places. It can be modified with undivided bench seat in rear to provide accommodations for four rather than three.

place—16%, or about 2,080 aircraft.

- Single-engine with more than five seats—7%, or about 910 aircraft.

- Single-engine, five-place—39%, or about 5,070 helicopters. A geographical subdivision of this category, which includes the AS-350, predicts that 52% of the sales of this type of civil helicopter will take place in North America (U. S. and Canada), 18% will be in Europe, and 30% will be accounted for by the rest of the world.

Program officials recognize that they will be competing head-on with the Bell JetRanger for this market, particularly in the U. S., and they are trying to make the price of the AS-350 competitive with that of the JetRanger. In the past, the French firm has had to cope with a reputation for relatively high prices for its smaller helicopters. In the case of the AS-350, the price is expected to be "slightly below 1 million francs" (about \$200,000) at 1976 economic conditions when the first deliveries begin in 1978. This compares with a price of approximately \$180,000 for the JetRanger 2.

Aerospatiale will have to sell about 500 aircraft before the breakeven point is reached on the program, according to company officials.

For those aircraft sold on the American market, much of the work, including final assembly, installation of the Lycoming engine, painting, interior configuration and installation of avionics, will be accomplished by AHC in the U. S. This will help in countering any future drops in the value of the dollar with respect to the French franc, and also will provide at least some protection against abnormally high inflation rates in France relative to the U. S. Both of these factors, Aerospatiale officials concede, have created additional handicaps for the Helicopter Div. in competing with U. S. manufacturers.

Europe itself remains a relatively soft market for Aerospatiale's helicopters. Jean-Claude Rebuffel, commercial direc-

tor of the Helicopter Div., acknowledged here recently that "we have not been satisfied with our sales in Europe in recent years."

He said that 65-70% of the division's sales in the past several years have been outside of Europe, and that the Middle East currently represents one of the best targets for new sales.

While the division is bracing for tougher U. S. competition on the export market because of a drop in U. S. military orders for helicopters, the French manufacturer continues to hold a strong competitive position with respect to its American counterparts. Aerospatiale recorded orders for 324 helicopters worth \$333 million in 1975, and 85% of these were export orders.

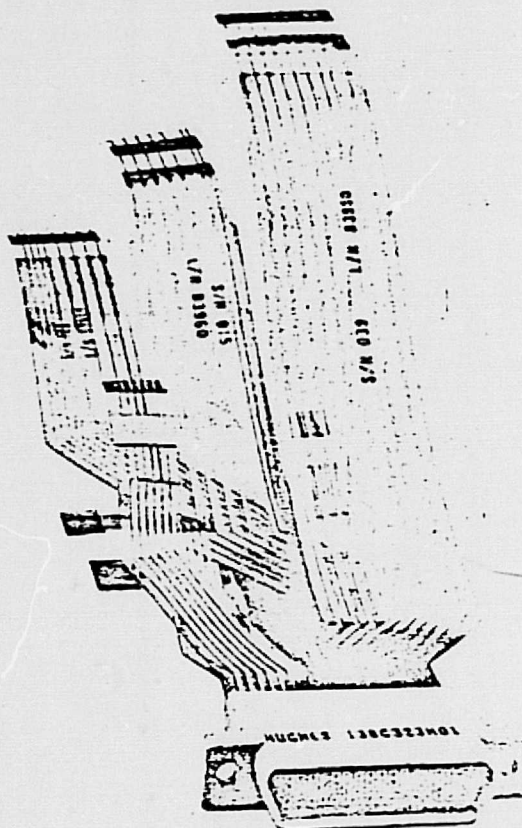
Of a total of 325 Aerospatiale helicopters delivered in 1975, 304 were for export customers. These export deliveries were worth approximately \$157 million, which Helicopter Div. officials believe compares very favorably with reported deliveries of \$210 million worth of U. S.-built helicopters to export customers.

Francois Legrand, director of Aerospatiale's Helicopter Div., also pointed out that Western European helicopter manufacturers as a group have been doing considerably better on the export market up to now than U. S. manufacturers as a group.

He cited 1974 export delivery figures for new helicopters of \$190 million for Western Europe compared to \$124 million for U. S. manufacturers.

Despite this situation, Legrand declared himself less optimistic than many other observers of helicopter markets, both military and civil. He cautioned that potential military spending cutbacks, coupled with a continuing depressed economy that is slowing civil sales, are clouding the short-term outlook. For the longer term, he is anticipating a much stronger U. S. export effort because of diminished military sales in the U. S.

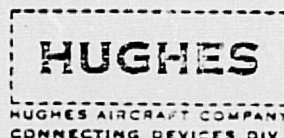
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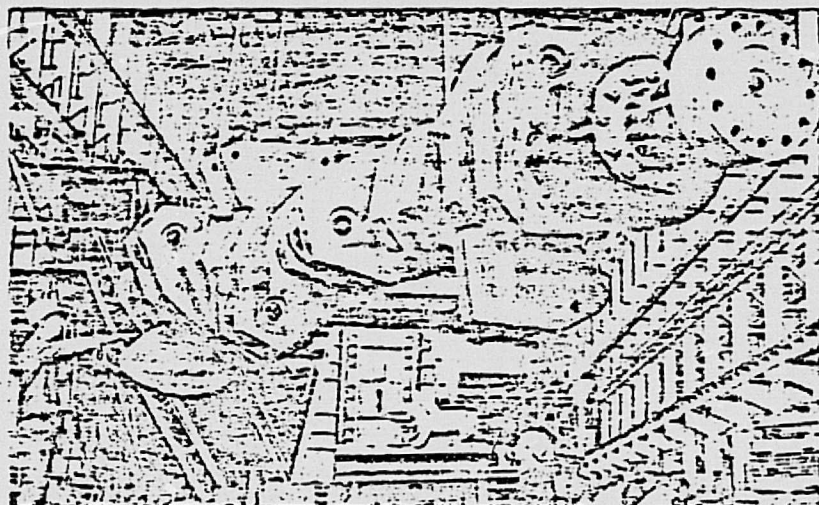


We crack the tough ones.

CASTINGS LIKE FORGINGS

• THE PIONEERING CAST CRANKSHAFT IS USED SUCCESSFULLY IN A 5,000 hp DIESEL

A group of engineers from Burmeister & Wain — an internationally known Danish company that manufactures heavy-duty marine engines, licences for whose products are used in 19 countries — recently came to the Soviet Union on a visit. They got acquainted in the latest technique for manufacturing crankshafts, the electroslag casting technique (ESC) developed at the E. O. Paton Institute for Electric Welding. Licences for ESC technique are available through V/O LICENSINTORG.



BURMEISTER & WAIN SPECIALISTS COMMENT ON ESC:

A. KNUDSEN,

President of Burmeister & Wain:

"I wish to congratulate the Russians on their new technology. ESC solves many problems in making marine diesel crankshafts. We realised that as soon as we saw the work at Briansk and Kiev."

Prof. V. JEPPESEN,

Danish Higher Technical School:

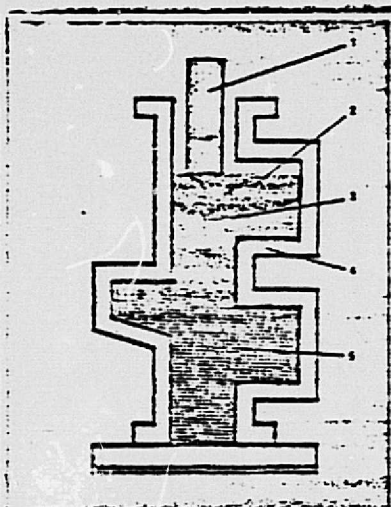
"Men will seek jobs in foundry shops equipped with ESC."

E. HANSEN,

Chief Engineer, Diesel Engine Works:

"We can gain many benefits from ESC. We will be happy to co-operate with the Russians in the ESC field."

B. I. MEDOVAR,
Academician, Ukrainian SSR
Academy of Sciences,
G. A. BOIKO,
Cand. Sc. (Tech.), both of
E. O. Paton Institute for
Electrical Welding



Schematic diagram of electroslag casting.

- 1 — melted electrode
- 2 — slag
- 3 — molten metal
- 4 — water-cooled crystalliser (mould)
- 5 — cast

Which is it to be — gradual modernisation or a revolutionary shake-up? Ninety per cent of industrial managers opt for the first, and only 10 per cent, the best brains in production, choose the second revolutionary approach and really new techniques. But in the end, they are the winners.

Any steel worker knows that forgings are mechanically better than castings. The critical parts of IC engines, high-pressure pipes, etc. are forged not cast.

But castings made with ESC are every bit as good as forgings. And it's much easier to make the odd-shaped pieces.

Electroslag casting derives from the internationally known Soviet electroslag remelting technology (ESR) — a process for which V/O LICENSINTORG has

The world's first cast crankshaft (1) for a 5,000 hp marine diesel engine.

Electroslag casting furnaces produce casts in no way inferior to forged pieces. Photo: The electroslag casting installation at the Bryansk Machine Works (2).

granted licences to companies in France, Sweden, Japan, the USA and many other countries. Castings made with ESR are used in a wide range of critical assemblies and components. In France, for example, the Concorde undercarriage is made of ESR metal. Yet despite many advantages, ESR furnaces can still only produce castings.

ESC TECHNOLOGY PRODUCES CASTINGS THAT NEED ONLY MINIMAL MACHINING

ESC technology is used at the Bryansk Machine Works in the Soviet Union to make marine diesel crankshafts. The first of these has already been installed in a 5,000 hp diesel to power a 15,000-ton dry cargo ship. ESC is used to advantage in the fabrication of connecting rods, valve stems, valves and other marine engines parts.

ESC is also used in the Soviet power generating equipment industry for gates, shut-off valves and high-pressure vessels, the latter being cast complete with connection pipes. The number of welds is sharply cut down. Cast austenitic steel tubing — an essential product for nuclear power generation — can also be made to advantage by electroslag casting.

ESC offers certain advantages in the manufacture of rolls for rolling mills, cold tubing mill passes, forging dies, and other heavy metal equipment.

ESC tools have one-and-a-half to two-and-a-half as much strength as conventionally made products as their dendrite axes are optimally orientated in relation to the cutting edge.

An important advantage of this new technology is that it gives workpieces virtually unlimited weight and shape with fairly unsophisticated equipment. The electroslag-cast components for the article desired are suitably placed in a mould, and then molten metal is poured to unify the components. The final product is an integral piece absolutely even at all points. This technique can produce a crankshaft of any length and with crankpins in any position.

The individual parts of any item can be made of different metals according to need. And ESC "successive casting" can be used for bimetallic items.

ESC OPERATIONS MAY BE CARRIED OUT IN STANDARD ESC FURNACES OR SPECIALISED INSTALLATIONS

The required chemical composition is achieved by using suitable electrodes, and the molten metal is effectively shielded against oxidation by a layer of molten slag, which also acts as an active refiner by assimilating non-metallic impurities — especially sulphur, nitrogen and oxygen, and under certain conditions, hydrogen.

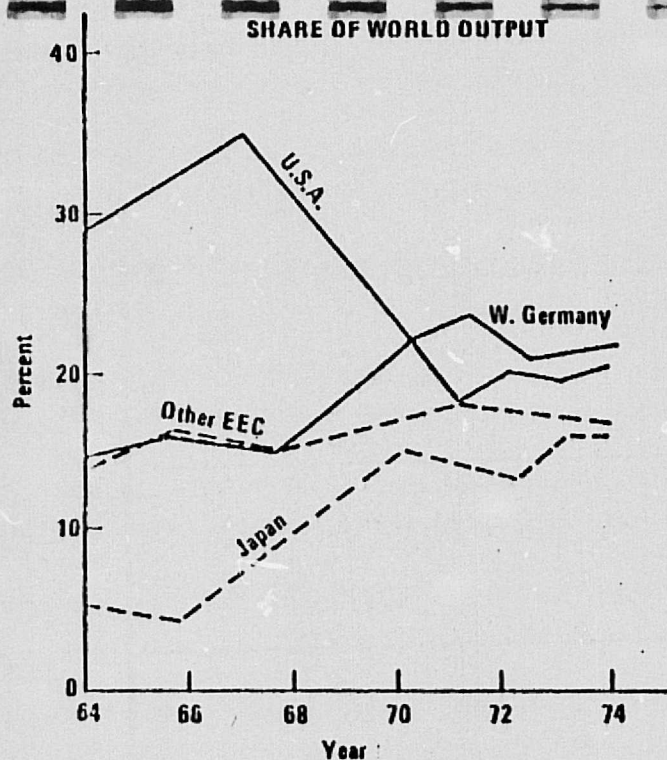
Studies carried out in the Soviet Union, the USA, Japan, France, Czechoslovakia and elsewhere have demonstrated that electroslag castings and conventional forgings have equally effective properties, while the former are superior for density and isotropy. Electroslag castings are virtually independent of the obtained macrostructure for their mechanical properties and exhibit high transverse and longitudinal isotropy both in crystals and at crystal boundaries.

Soviet industrial experience shows that the cost of a ESC equipment is recouped in two to two and a half years. Functional and relatively inexpensive, ESC equipment can be effectively operated in machine building enterprises of any size. ESC meets the most exacting standards of sanitation and work hygiene.

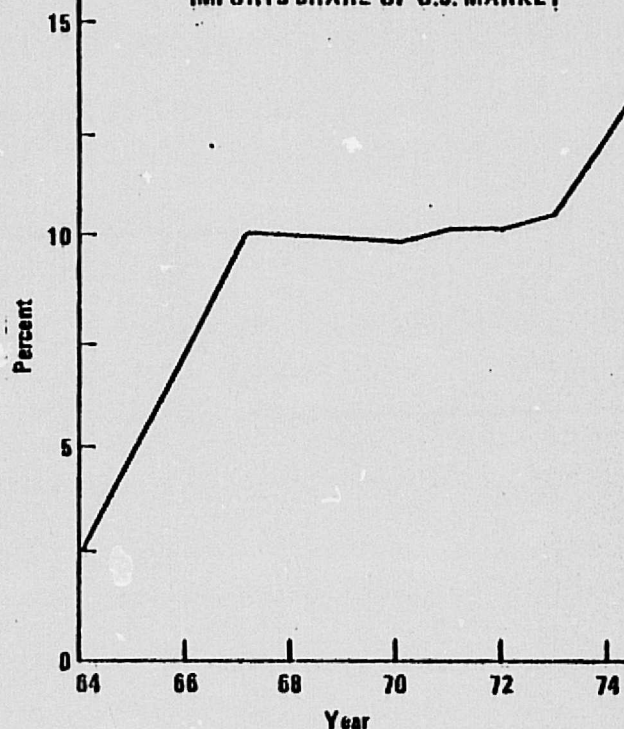
Developed at the E. O. Paton Institute, the ESC technology and process equipment have been patented in the USA, Great Britain, Denmark, France, the FRG, Japan, Austria, Sweden, Canada, Belgium, and elsewhere.

 **V/O LICENSINTORG,**
31 Ul. Kakhovka, Moscow 113461;
telex: 7246.

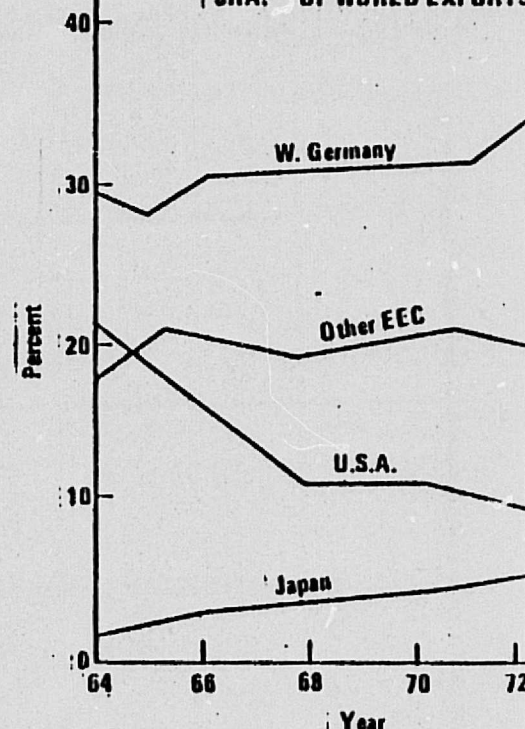
SHARE OF WORLD OUTPUT



IMPORTS SHARE OF U.S. MARKET



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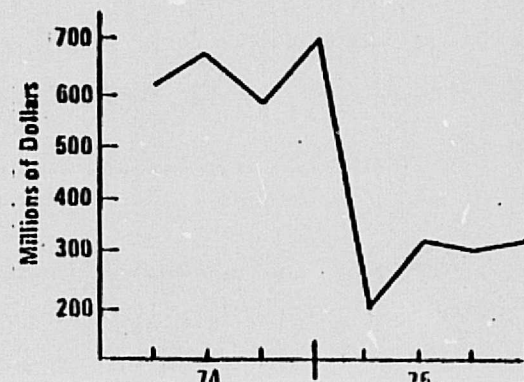


- West Germany Overtook U.S. As Leading Producer of Machine Tools in 1970.
- West Germany Sold \$2.8 Billion in 1974, U.S. Second with \$2.6 Billion
- American Industry Bought 15% of its Tools Abroad in 1974, Imports Share of U.S. Market Tripled Since 1965.

SOURCE: Statement of James Gray, National Machine Tool Association

- Machine Tool Orders Plummeted in First Quarter 1975, Recovery in First Quarter 1976 Mostly U.S. Orders.

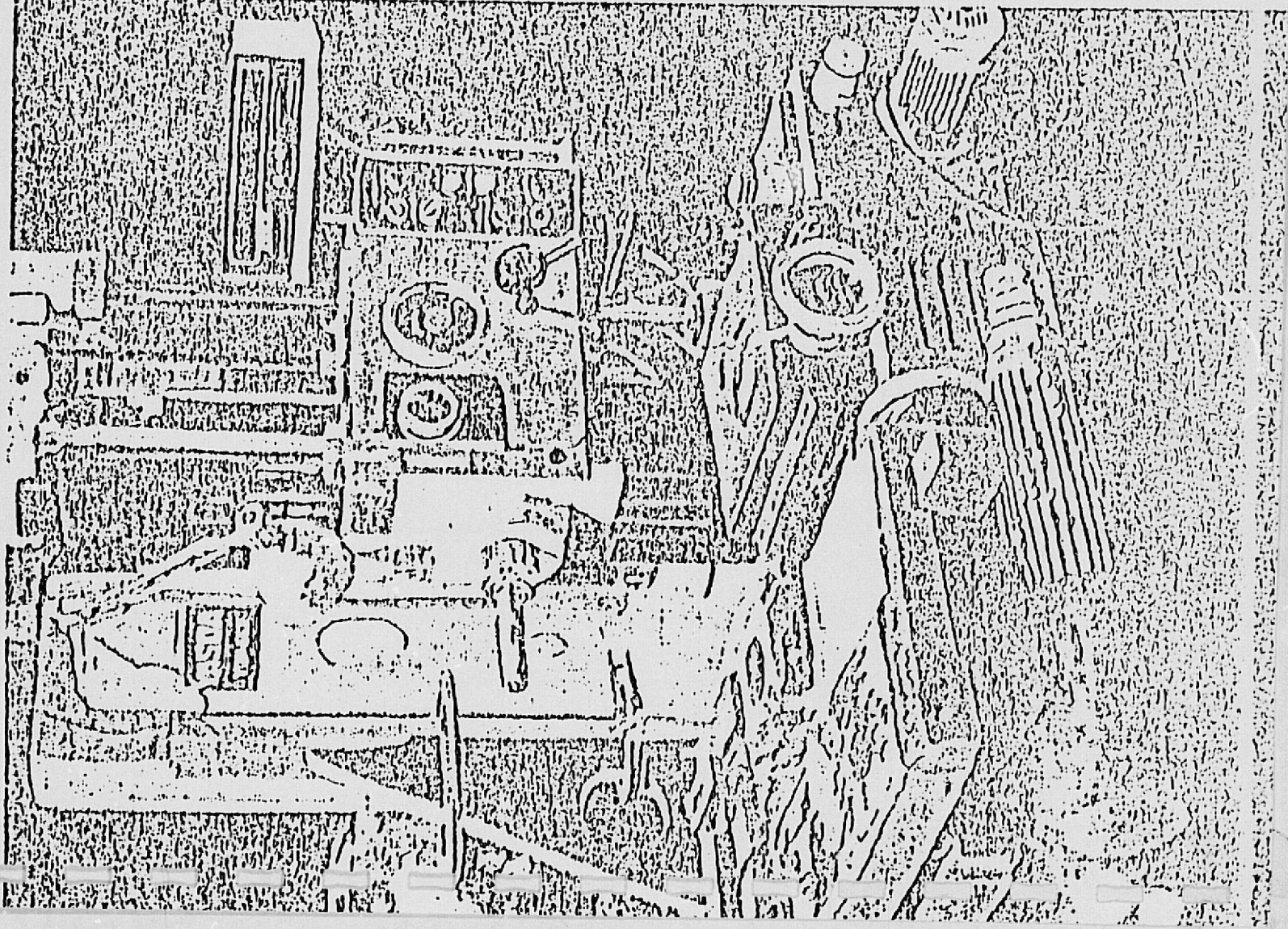
SOURCE: Business Week May 3, 1976



Cosmopolitan Tools for America's Factories

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The machine-tool industry, literally as well as figuratively, provides the cutting edge for mass-production technology. Britain was aware of this when, at the start of the industrial revolution, it tried to protect its lead in manufacturing by prohibiting the export of machine tools. But that effort quickly collapsed, and today the industry flourishes in more than a score of countries.

West Germany overtook the U.S. as the world's leading producer of machine tools in 1970; last year the Germans turned out \$2.3 billion worth of them. The U.S. ranked second, with \$2.6 billion, followed by the U.S.S.R. and Japan. Britain is now in seventh place, behind Italy and France.

International trade in machine tools has been growing vigorously. The U.S. is a net exporter and is particularly strong in complex, numerically controlled machinery. But American industry now buys 15 percent of its tools abroad. The share of market taken by imports has tripled since 1965. One reason for this increase was that domestic producers developed such large backlogs that delivery times, in some instances, became inconveniently long. And foreigners sell many simple tools at lower prices.

Some notable imports are pictured on these and the following pages. The portraits are the work of seven contemporary artists, commissioned by *Fortune* to capture, impressionistically, in a way photography could not do, the elegant sophistication of the machines that shape the products of modern industry.

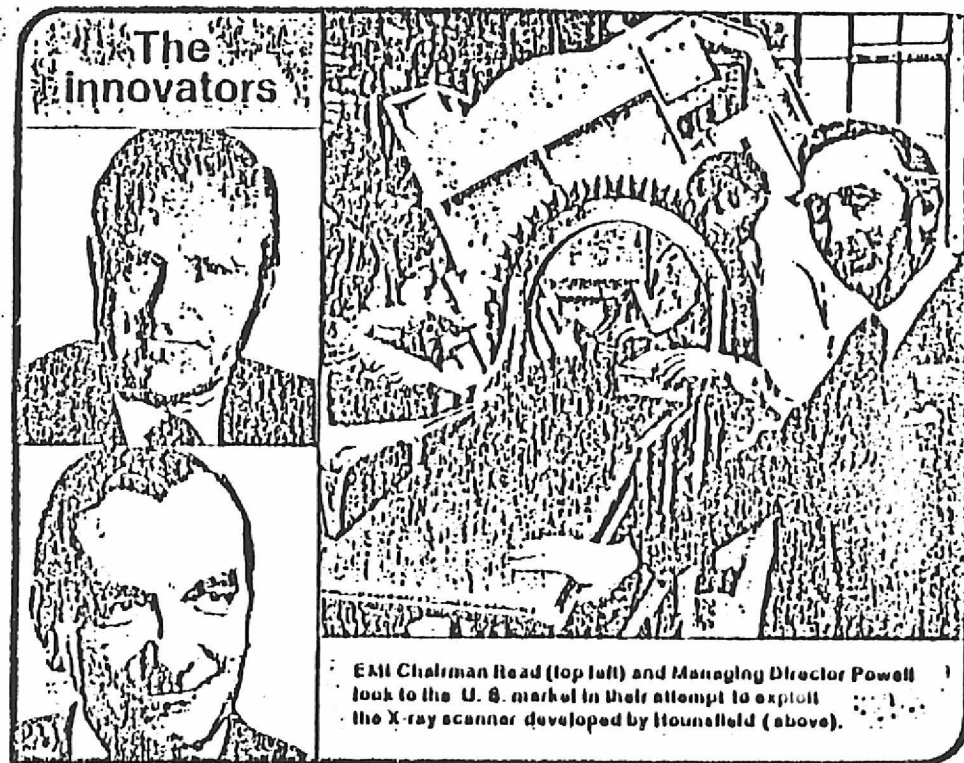
- Britain's EMI Ltd. Banking on Pioneering Work in Development of X-Ray Scanners to Maintain U.S. Leadership

- Proven Value in Pinpointing Tumors & Vascular Lesions Without Painful/Dangerous Surgery & Dye/Air Studies

- Four Year Old Brain Scanner — Sales in U.S.

- One Year Old Body Scanner Now in Evaluation in Mayo Clinic & Malmkrodt Institute

- Potential U.S. Market
\$1B - \$1.5B



Source: Business Week, 4/19/76

Can Britain's EMI stay ahead in the U. S.?

It all depends on its X-ray scanning machines in a tightening market

Britain's EMI Ltd. would like to double its annual sales to \$2 billion by the early 1980s, and the growth will come not only from the company's traditional entertainment business, but in a highly specialized area—medical electronics. The company is banking on its pioneering work in the development of computerized X-ray scanning devices to maintain its U. S. leadership against increasing competition from established electronics giants.

Last year, 61% of EMI's sales and 62%

18%, a consequence of EMI gearing up quickly to produce its diagnostic body scanners, which it is marketing aggressively in the U. S.

However, just as EMI's music business ran into competition from U. S. companies, so do its sophisticated X-ray scanners now face a growing array of rivals. Big names in medical equipment—General Electric Co., Ohio-Nuclear Inc. (a division of Technicare Corp.), Pfizer Inc., and Varian Associates—are all in the scanner market and all have assembly capacity, sales, and service organizations in place. To date, Ohio-Nuclear has orders for 161 scanners, with 48 in place. Even with EMI's jump on the market, the ability of the U. S. companies to react to service

and vascular lesions without dangerous and painful air studies. Worldwide, nearly 300 hospitals have EMI's brain scanner installed, including several neurological institutes that have more than one unit.

The year-old whole-body scanner, now in clinical trials at the Mayo Clinic and Washington University's Mallinckrodt Institute, promises diagnostic feats that could eliminate most dye studies and exploratory surgery. Radiologists in the U. S. predict that the device will be required equipment in every hospital having 200 or more beds—a market of 2,470 in the U. S. and 293 in Canada. At between \$360,000 and \$550,000 for each EMI scanner, the company appears to have opened a lucrative market.

The biggest market. "I am a firm believer in creating business on the back of innovation," says Oxford physicist and EMI managing director Dr. John A. Powell. And both Powell and Read are believers in the U. S. market for that business. Both men were recruited from British subsidiaries of U. S. companies—Powell from Texas Instruments Inc.'s British operation, and Read from Ford Motor Co. Ltd. Read rose through the financial, service, and sales departments at Ford before moving to EMI in 1965 as managing director under then-chairman Sir Joseph Lockwood. Insiders say it was Powell, who came to EMI in 1971, and Read who pushed EMI into electronics in the U. S. despite Lockwood's reluctance to compete against U. S. electronics firms.

Initially, EMI's scanners had a speed advantage over its competitors. But in December, General Electric, Varian Associates, and others, announced that they were bringing faster machines into the market. GE is promising a five-second scan (vs. EMI's 20 seconds) with the \$595,000 device it is installing for clinical trials this week at the University of California's San Francisco medical center. Delivery of its first commercial units is scheduled for mid-1976. Varian is testing a six-second scanner, and last week Ohio Nuclear announced that its latest device had reduced scanning time to 18 seconds. Says Paul Staulcup, an assistant in the radiology department at New York City's Mt. Sinai Hospital, "Whatever you do in this market may be like buying last year's car model" because the technology is changing so rapidly.

Right now, EMI has 465 scanners on order, including about 90 for the new whole-body units. But GE, which has



EMI Chairman Read (top left) and Managing Director Powell look to the U. S. market in their attempt to exploit the X-ray scanner developed by Hounsfield (above).

of its \$88 million in earnings came from overseas operations. Most of that was from the company's recording labels—Capitol, Angel, and others. But EMI has faced stiff competition from U. S. companies in this area, as well. So its chairman, John A. Read, who says he has tried "to expand away from a rather narrow base," wants to build on EMI's strengths in the sciences, as well as music and the arts.

The results of that determination are surfacing quickly. Since becoming chairman 15 months ago, Read has seen the contribution of music to the company's profits drop to 46% from 65%. Sales from electronics went up during the same period to 33% from

problems and changing technology may ultimately give them the edge.

The development EMI's body scanner is an outgrowth of its brain scanner, which it introduced four years ago. Together, the two machines have contributed an estimated \$10 million to EMI's latest six-month earnings (to December 1975) of \$65.5 million on sales of \$633.2 million. What makes the scanners desirable is their ability to produce cross-sectional pictures of internal body structures that detail organs and lesions never before visible on conventional X-rays. Based on a process called computed tomography (CT), the earlier brain scanner has already proven its value by pinpointing tumors

28% to 30% of the conventional X-ray market in the U.S., is moving up fast. GE has an established service network of 1,200 people vs. EMI's 120, which has enabled GE to log 55 scanner orders even before the first clinical trial. Competitors complain that GE salesmen are locking hospitals into GE equipment that has yet to be proven, but several hospital teams indicate that they want GE equipment because it is manufactured and assembled in the U.S. "Downtime is an important factor in these machines," says one hospital engineer. "We have to be certain we can get parts and service quickly—and GE has a pretty good reputation."

High performance. But EMI has doubled its assembly capacity in the last three months, and further expansion is planned. Dr. Ronald G. Evens, chief of radiology at Mallinckrodt Institute, discounts the parts-and-service liability of a foreign product. "Siemens and Philips are good competitors of GE and Picker for conventional X-ray systems, and they do most of their assembling in Europe," he says. Evens has seen 400 patient-scans on the EMI machine and is highly enthusiastic. "We have been able to differentiate between benign and malignant tumors with over

'Downtime is an important factor in these machines,' says one hospital engineer

90% success in pancreatic and other studies," he says. With 80% fewer dye studies, the EMI machine has also successfully detected tumors of the kidney, pelvis, liver and chest.

Evens believes that EMI has an advantage in that "they have three years of experience, a good group of 'imaging' engineers and computer scientists, and have demonstrated their ability to improve their machine." Moreover, most of the early CT scanning techniques were developed by Dr. Godfrey Hounsfield, who works at EMI's British research center. Even Dr. Richard K. Lawton, GE's consulting physician, suggests that Hounsfield "may well be in line for a Nobel Prize, one of these days."

Besides medical electronics, EMI also makes color TV sets in Australia, where it has a marketing arrangement with Toshiba. That business has been booming since the introduction of color transmission in 1975. Another boost came from the sell-off of its disastrous 50% interest in Voxson, the Italian

Developing talent at EMI



Capitol has 10% of the U.S. record market with such stars as (clockwise from left) Grand Funk, Natalie Cole, The Band, Helen Reddy.

manufacturer of radio, TV, and hi-fi equipment.

Music is big. Music is still nearly half of EMI's business, however. Leonard G. Wood, the company's assistant managing director in charge of music, claims that EMI has about 20% of the world music market, or \$500 million in sales. "Talking about the world," he says, "we're No. 1," although he concedes that EMI runs "nose to nose" with Columbia. All told, EMI operates 30 companies that record, manufacture, distribute, or sell records and tapes worldwide.

The U.S., however, represents half of the world music market. And when EMI held the Beatles contract, its Capitol label was No. 1 in the U.S. When the Beatles broke up in 1970, Capitol suffered its first loss. The following year EMI sent V. Bhaskar Menon, the head of its music operations in India, to take over at Capitol. Menon, whom one insider terms "rough and tough," revamped the company, lopping \$10 million from its payroll and reducing its roster of recording artists. A Scranton (Pa.) record company was sold as well as 1,000 acres of California orange trees.

Menon's cutbacks also extended to the number of Capitol's annual releases—from 300 albums when he arrived to 100 last year. He prefers to develop new artists, rather than to get into "heroic signing battles over individuals with big names," he says. Yet, the Capitol label has slipped to No. 3, behind Columbia and Warner Bros.

Inc. But Menon says, "Why be No. 1 if you're going to lose money?"

Capitol is making money today, and Menon wants to expand its retail activities. But one insider suggests he will have a hard time doing that, because "Capitol's distribution facilities are poor, they're too small for volume distribution, and there's not enough of them." Moreover, this source notes that Capitol's vice-president for artists and repertoire, Albert E. Coury, who was responsible for developing such talent as Helen Reddy and Natalie Cole, quit this year after a management shuffle.

Slower growth. Read, however, continues to count heavily on music as well as electronics to achieve his long-range goal. He expects slower growth from EMI's leisure businesses—hotels, restaurants, sports facilities, and bingo parlors in Britain—because of the economic squeeze that the ailing British economy is putting on discretionary income. Nevertheless, he did shell out \$12 million last year for 104 bingo parlors.

Since EMI is committed to growth in all these areas, its management is changing its style. "EMI has had a distinguished history of developing technological breakthroughs," says Powell. He points, for example, to the company's development of a high-definition TV system in 1937. "But," he adds, "they were never followed up or exploited." Powell is determined that the new scanners will be different. Read agrees. Unofficial estimates place his target for scanner sales at \$200 million by 1978.

TRAIN BACKUP

TURBOTRAINS

- O AMTRAK BOUGHT 6 TO TRY AND LIKED THEM (FROM FRANCE)
- O HAVE ORDERED 7 MORE FROM ROHR WHO OBTAINED LICENSE FROM FRANCE
- O FOUND BETTER THAN U.S. (SIKORSKY-PULLMAN STD) MAINTENANCE/RELIABILITY

ELECTRICS

- O FRENCH LOCOMOTIVE BEING LEASED BY AMTRAK FOR TRIALS
- O SWEDISH LOCOMOTIVE BEING LEASED BY AMTRAK FOR TRIALS
- O WILL COMPARE TO G.E. IN SERVICE
- O IF FOREIGN CHOSEN WILL HAVE BUILT HERE

AMTRAKS CLEAR MESSAGE - IMPORTING TECHNOLOGY
NOT PRODUCTS

[PASSENGER TECHNOLOGY IMPORTS VS. FREIGHT EXPORT]

(R. ROLLINS CONTACT WITH AMTRAK)

The silent crisis in R&D

Economists bewail the impact of lower spending on growth and profits

Even if the apparent economic recovery takes a firm hold, some concerned economists are warning that the U.S. may face a serious slowdown in its long-term growth rate because of the protracted slump in spending for research and development.

Merton Peck of Yale calls it "the silent crisis"—not obvious like other national crises but nonetheless real. Harvard economist Zvi Griliches, one not given to hyperbole, says: "The slack

the next 10 years alone could reach \$100 billion, not counting the loss of improvement in the quality of life that cannot be measured in GNP dollars.

Moreover, productivity gains, which reduce unit costs, are a prime factor in combating long-term inflation. Thus, by scrimping on R&D, the nation is fighting the inflation battle with its right arm in a sling.

Losing ground fast. The slowdown in research spending has been dramatic. From 1953 to 1961, R&D expenditures, adjusted for inflation, increased at an average rate of 13.9% a year for government and 7.7% for nongovernment, according to the National Science Foundation. From 1961 to 1967, government-funded R&D increased 5.6% a year and private R&D 7.4%. But from 1967 to 1975, government R&D shrank 3% a year, and nongovernment spending rose a mere 1.5% a year.

Recent studies confirm not only that R&D is a significant factor in the nation's growth but also that companies themselves are missing a good bet by not putting more of their dollars into R&D. The major findings:

- Organized R&D projects of the kind that are covered in company budgets account for about 40% of the total increase in U.S. productivity. This means that a dollar spent on R&D has a far greater impact on economic growth than a dollar invested in physical capital.

- Industry earns an average 30% rate of return per year on its R&D spending—about twice the return that companies get from their capital investments.

- On the average, the largest companies do not spend proportionately more or less than smaller companies, and their rate of return per dollar of R&D expenditure is also similar. Therefore, tinkering with the market structure of U.S. industry to spur R&D spending offers no hope of a payoff.

Three sources feed the stream of national economic growth: capital investments, increases in both the quantity and quality of the labor force, and improvements in technology. Although economists have long labored over the

role of each of these three factors, they now agree that technological gains have been as important to the economic growth of the U.S. as increases in capital and labor. Fully one-third of the measured growth in GNP has come from technological progress, they say.

The payoff. Technological progress stems from a variety of sources, including such informal ones as the amateur inventor pattering in his garage on weekends or the manager who gets a idea on how to organize the production line better. The major question is how much of this progress has resulted directly from organized R&D. Griliches' econometric findings put this contribution at 20% to 25%. And a recent study by Nestor E. Terleckyj of the National Planning Assn. conservatively estimates that in 1948-66 organized R&D was responsible for at least 32% of the improvement in technology. Considering that industry invests about 10 times as much in plant as in R&D, \$1 of R&D has almost four times the impact on growth that \$1 invested in plant and equipment has.

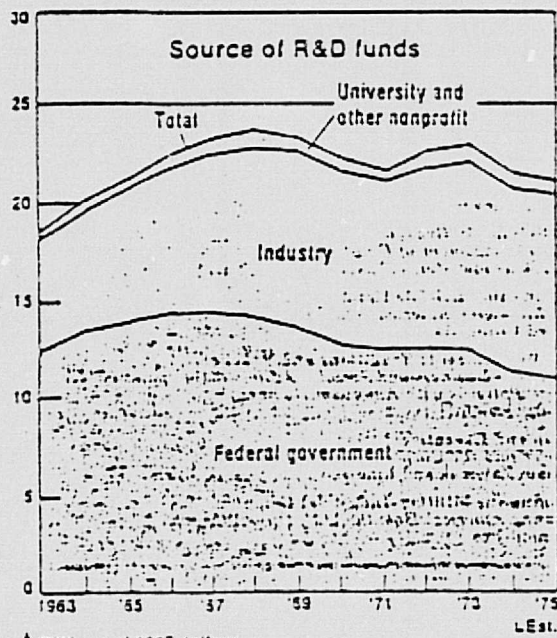
Spending on R&D has not only paid off in a big way for the country as a whole but has also produced high rates of return for the industries that do the spending. A paper by Griliches shows that in 1957-65 R&D produced an average annual 27% rate of return, based on the depreciated life of the expenditure. This, he says, is about twice the return on physical capital investments by the 383 companies in his sample.

Using a different set of data, Terleckyj finds a direct productivity return of about 30% a year on R&D in manufacturing industries in 1948-66. Moreover, he finds, some industries that do little of their own R&D but buy from R&D-intensive industries achieved productivity gains of 30% per year. For example, airlines benefit from the R&D done by the aircraft industry.

The findings of Griliches and Terleckyj apply only till the mid-1960s, the latest years for which detailed data are available. But a study by Edwin Mansfield of the Wharton School seems to indicate that high rates of return persisted into the 1970s. Mansfield used a sample of 17 run-of-the-mill innovations, ranging from a metal process introduced in the late 1950s to a door control mechanism marketed in the early 1970s. He shows an average annual rate of return of 25% to the innovating company, after adjustment for unsuccessful R&D efforts, and a return of well over 50% to other users as a whole.

Why the slump? Given the high rates of return on R&D, economists are hard-pressed to explain why industry spending has lost its historically robust growth. Industry R&D amounted to 1.5% of total sales in 1967, peaked at

The prolonged slump in R&D



▲ Billions of 1967 dollars

Data: National Science Foundation, BW

growth of the past seven years in research and development spending will come home to roost."

Economists in this group maintain that the slowdown in long-term growth has already been set in motion by the slump in R&D spending since the late 1960s (chart). They have no pat solutions to the problem, and their new findings raise almost as many questions as they answer. But their message is clear: unless the nation steps up

investment in developing and marketing improved processes and products, the U.S. economy is doomed to grow more slowly in the 1970s and 1980s than it did in the 1960s. The potential loss in gross national product in

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Mansfield: "R&D isn't worth anything alone. It has got to be coupled with the market."

2.5% in 1969, and has now fallen below 2%.

Some businessmen contend that increased government regulation of industry has put a crimp in private R&D. But Terleckyj argues that it should only open vistas for new and better products and would not have an overall negative impact. Some critics suggest that the oligopolistic market structure of U.S. industry is the cause. But economists who have analyzed the relationship between company size and technological progress deny this claim.

There are two conflicting views of the impact of big companies on innovation. One theory, first formulated by the late Joseph Schumpeter and eloquently elaborated upon by John Kenneth Galbraith, holds that R&D is carried out much more productively by very large companies. To foster innovation, this theory would call for relaxation of the antitrust laws. In total contrast, some economists and most consumer advocates maintain that large companies stifle innovation, so antitrust laws should be enforced more vigorously.

The overwhelming evidence is that neither theory fits the facts. "For practically all industries," Wharton's Mansfield says, "the data indicate that very big firms do not carry out more innovation relative to their size than do smaller firms." Instead, economists find a threshold effect. Explains Mansfield: "In order to do much research and development, a firm must be of a certain minimum size—which, of course, vary by industry. Beyond that, innovation seems to be proportional to size." He does note exceptions, though. For example, Du Pont spends more on R&D, relative to its size, than smaller chemical companies do.

dollar than somewhat smaller companies get, Mansfield adds, but this disadvantage is offset by their ability to do a superior marketing job. He says: "Small and large firms should be looked at as complements to each other. You need the small firm's flexibility to move quickly, especially in the initial stages

Companies are missing a good bet by not putting more money into R&D

of innovation, and you need the very large firms with their huge capital resources, large numbers of researchers, and marketing knowhow."

How to cash in. "R&D isn't worth anything alone," Mansfield maintains. "It has got to be coupled with the market. The innovative firms are not necessarily the ones that produce the best technical output but the ones that know what is marketable."

Economists who agree cite as an extreme case the Soviet Union's problems in improving productivity through R&D. "They keep spending tons of money on R&D, but they don't get much out of it," says a government economist who specializes in Soviet affairs. "The Soviets are right at the frontiers of research in the lab. It's getting from the lab to metal-bending and into production that is the trick."

Charlotte Schroeder of the University of Virginia, an expert on the planned economies, notes that the Russians are turning out engineers and scientists by the drove. But because of the emphasis on today's production, managers have little incentive to shut down for retooling and, thus, are not receptive to new ideas. "The research-



Griliches: "The stock growth of the past seven years..."

different wavelengths," she says.

Resistance to innovation is not confined to planned economies, Mansfield finds. In a survey of the R&D executives of 20 major chemical, drug, and electronics companies in the U.S., he found an opinion that the success rate of innovation would have been boosted by 50% if the R&D results had been fully and properly exploited by their companies' manufacturing and marketing people. To confirm this evaluation, Mansfield put the same set of questions to non-R&D executives. Their estimate turned out to be even higher than that of the R&D managers.

Incentives. While economists agree the companies should invest more heavily in R&D and should improve their output from it, by no means all of them advocate that government should provide special tax incentives. "Since R&D really is investment, there's already a tax benefit because companies can write it all off," says William Fellner, of the American Enterprise Institute. And Yale's Merton Peck says: "I'm against government incentives. The best thing to get private R&D moving is get this economy off its bottom."

But Mansfield disagrees. "We need a general incentive," he suggests. "Let's explore tax incentives carefully." Edward F. Denison of the Brookings Institution, a pioneer in the study of economic growth, says: "I have always been against tax incentives for R&D. But after seeing Mansfield's work on the rate of return, I'm reconsidering my position."

Although Fellner is against tax incentives, he favors more federal funds for R&D, especially where the risks for private industry are enormous, as in energy development. In the 1977 budget, federal funds for R&D increased only 10% in inflation-bloated dollars, and Fellner notes that real R&D will rise less than real GNP. "I would not try to save on the R&D budget," he says.

Griliches believes that more federal dollars should be going into the universities, where he says the nation has a high-class scientific establishment that is "now underutilized and malnourished." The low rate of utilization, he concedes, is partly the universities' own fault. "They expanded, thinking that government funds would be flowing forever," he says. Still, he says, university labs represent an underutilized resource that should be put to work.

Like Fellner, Mansfield argues for more federal R&D funds, but he also does not advocate opening all the money taps. "I'm not for throwing a wad of money into machine tool research, for instance," he says. "What we do need is a concerted research effort to determine the most effective R&D times of effort."

TABLE 7.—ALTERNATIVE FORECASTS OF PHYSICS PH.D.'S 1970-80

Years	Office of Education	Cartter	NAS-NRC	Model A	Model B
1969-70*	1500	1500	1500	1500	1500
1974-75	2153	1853	2153	1134	1189
1979-80	2492	2634	3350	731	786

Source: Office of Education, Cartter, NAS-NRC from Cartter; Models A and B, from the recursive model of Tables 4 and 5, as described in the text.

* The various projections use different base year numbers of Ph.D.'s due to differences in the source of data. National Academy of Science-National Research Council (NAS-NRC) data differ somewhat from those of the Office of Education. I have set the base year number as 1500 and made projections on the basis of implicit percentage increases in the actual forecasts.

entrants will ameliorate physics market problems; according to the standard calculations, increases in supply will exacerbate the potential imbalance of the 1980's due to the likely fall in demand for faculty. While different changes in exogenous variables such as a sudden sharp increase in federal R&D spending on energy would significantly invalidate our forecasts, it is evident from Table 7 that economic responsiveness has a first-order effect on the market and should be taken into account in manpower analysis.

III. Summary

The principal findings of this study can be summarized briefly:

1) The number of physics students has varied greatly in the postwar period, declining in the recent collapse of the science market after a decade of rapid increase. These changes result from economic responses to salary or job opportunity incentives, with fairly large elasticities of supply for physics salaries ranging from about unity in the short run to 3 or 4 in the long run at the graduate level, and from 2 in the short run to 4 in the long run for B.S. recipients.

2) Salaries of physicists have fluctuated significantly relative to other wages and salaries, rising in the post-Sputnik

boom period and falling rapidly in the late 1960's and early 1970's. The bulk of the change in salaries can be attributed to R&D expenditures and the R&D policies of the federal government, with changes in supply having a smaller, though significant, effect.

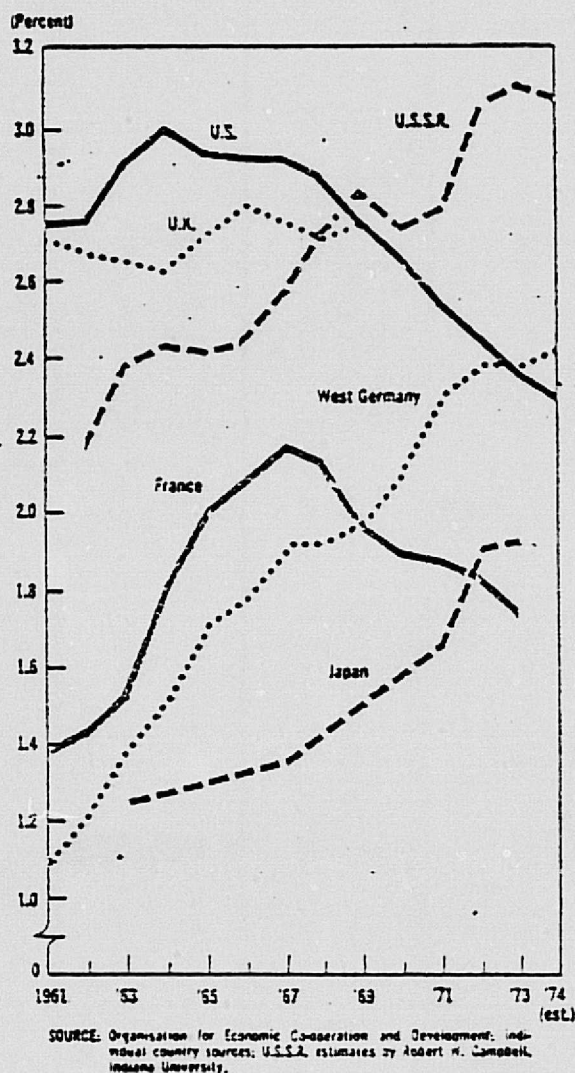
3) Developments in the physics market, as in several other high level labor markets, appears to be well described by a simple recursive model which exploits the time delay in supply due to lengthy training programs. As a result of the recursive structure, large numbers of physics graduates create a market setting likely to reduce enrollments and future degrees in the field in accord with the cobweb scenario.

4) In the absence of a sharp increase in demand in the near future, market adjustments, especially on the supply side, are likely to lead to far fewer Ph.D.'s in physics than indicated by standard forecasts. While the market still faces the major shock of a demographic-induced decline in demand for faculty in the 1980's, supply and salary adjustments will provide an important buffer to the decline.

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Figure 1-1
R&D Expenditures as a Percent
of Gross National Product (GNP),
by Country, 1961-74



cost, and effectiveness of R&D—as well as inconsistencies in GNP accounting—the measure is relatively gross. Interpretations of the indicator, therefore, should focus on general trends rather than specific numerical values.

The fraction of the GNP of the United States devoted to R&D has declined steadily over the

last 10 years, falling nearly one-fourth from its peak level in 1964. The decline, as discussed elsewhere in this report,⁴ is due primarily to reduced growth of expenditures by the Federal Government for R&D in the defense and space areas; increases in R&D funds from all other sources combined kept pace with growth in the GNP. In the case of France, the only other country of those studied which showed a long-term decline in this indicator, the reduction appears to result largely from a slower growth in government R&D expenditures for national defense and nuclear energy.

Both Japan and West Germany recorded substantial growth in the proportion of the GNP directed to R&D. Underlying their growth were continuous large increases in R&D funding from both industry and government. Total R&D expenditures by Japan increased at an average annual rate of 21 percent between 1963 and 1973, and those of West Germany by 15 percent, as compared with 6 percent for the United States. More recently, annual increases between 1969-73 averaged 24 percent for Japan, 16 percent for West Germany, and 4 percent for the United States. While industry is the prime source of R&D funds in Japan and West Germany, funds provided by the government have grown relatively more than those from industry. Government funds for R&D in these two countries are concentrated on advancement of science and, to a lesser extent, on general economic growth and nuclear energy.⁵

For the U.S.S.R. this indicator is based upon limited information and should be regarded only as an estimate. The general upward trend in the proportion of the GNP devoted to R&D is believed to be valid, although the specific numerical values may differ significantly from the true values. Possible differences in the variety of activities regarded as R&D, as well as differences in GNP accounting, make international comparisons involving the U.S.S.R. particularly hazardous.

R&D Personnel

The human resources involved in R&D provide another comparison of the magnitude of national R&D efforts. The number of scientists

⁴ See the chapter in this report entitled "Resources for R&D".

⁵ Information on the distribution of government R&D expenditures among these and other areas is presented in a later section of this chapter.

Table 1-1. R&D expenditures as a percent of Gross National Product (GNP), by country, 1961-74

Country	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974 (est.)
R&D expenditures as a percent of Gross National Product														
United States	2.75	2.75	2.90	2.99	2.93	2.92	2.92	2.86	2.76	2.66	2.53	2.45	2.35	2.29
France	1.38	1.43	1.53	1.73	1.99	2.07	2.16	2.11	1.96	1.88	1.87	1.82	1.73	NA
West Germany	1.08	1.23	1.38	1.54	1.70	1.78	1.94	1.93	1.99	2.12	2.25	2.37	2.36	2.41
United Kingdom	2.69	NA	NA	2.62	NA	2.79	2.75	2.70	2.73	NA	NA	NA	NA	NA
Japan	NA	NA	1.25	NA	NA	NA	1.34	NA	1.50	NA	1.65	1.89	1.92	NA
U.S.S.R.	NA	2.18	2.37	2.42	2.40	2.42	2.55	NA	2.82	2.73	2.75	3.04	3.10	3.06
R&D expenditures (national currency in billions)														
United States ¹	14.3	15.4	17.1	18.9	20.1	21.9	23.2	24.7	25.7	26.0	26.7	28.4	30.4	32.0
France ²	4.4	5.2	6.3	8.1	9.8	11.0	12.4	13.3	14.2	15.2	16.8	18.3	19.8	NA
West Germany ²	3.6	4.4	5.3	6.5	7.8	8.7	9.6	10.4	12.1	14.5	17.4	19.8	22.0	24.0
United Kingdom ²	.6	NA	NA	.8	NA	.9	1.0	1.0	1.1	NA	NA	NA	NA	NA
Japan ²	NA	NA	321.1	NA	NA	NA	606.3	NA	933.2	NA	1,345.9	1,791.9	2,215.8	NA
U.S.S.R. ¹	3.8	4.3	4.9	5.4	5.8	6.3	7.2	7.9	9.3	9.9	11.0	12.2	13.3	13.9
Gross National Product (national currency in billions)														
United States	520.1	560.3	590.5	632.4	684.9	749.9	793.9	864.2	930.3	977.1	1,054.9	1,158.0	1,294.9	1,396.7
France	320.0	367.2	412.0	456.7	490.0	532.0	574.0	629.0	723.0	808.0	899.0	1,007.6	1,145.6	NA
West Germany	332.6	360.1	384.0	420.9	460.4	490.7	495.5	540.0	605.2	685.6	761.9	834.6	930.3	995.0
United Kingdom	24.4	NA	NA	29.5	NA	33.2	35.0	37.7	39.7	NA	NA	NA	NA	NA
Japan	NA	NA	25,592.1	NA	NA	NA	45,296.7	NA	62,259.9	NA	81,577.0	94,726.5	115,263.1	NA
U.S.S.R.	NA	197.2	206.8	223.2	242.1	260.1	282.0	NA	329.6	362.6	394.8	401.8	429.4	453.7

¹ Expenditures for performance of R&D² Expenditures for performance of R&D plus associated capital expendituresSOURCES: Organisation for Economic Co-operation and Development, *International Survey of the Resources Devoted to R&D by OECD Member Countries for 1963, 1967, 1969, and 1971*.

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West Germany: Statistisches Bundesamt, unpublished statistics.

U.S.S.R.: Dr. Robert Campbell, Department of Economics, Indiana University.

RELATIONSHIP OF R&D TO GNP
 CONSTANT 1977 DOLLARS
 BILLIONS OF DOLLARS

UNITED STATES				U.S.S.R.		
YEAR	GNP	R&D	R&D PERCENT	GNP	R&D	R&D PERCENT
1973	\$1747	\$40.6	2.33	\$933	\$28.9	3.10
74	1777	40.9	2.30	966	28.9	3.00
75	1725	39.5	2.29	985	30.9	3.14
76	1783	39.2	2.20	1005	30.1	3.00
77	1890	39.9	2.11	1025	30.8	3.00

WEST GERMANY				JAPAN		
1973	\$465	\$11.0	2.36	\$552	\$10.6	1.92
74	480	11.5	2.41	543	10.6	1.95
75	461	11.1	2.41	548	10.6	1.93
76	480	11.5	2.41	548	10.6	1.93
77	504	12.0	2.41	548	10.6	1.93

U.S.

The GNP for FY 1975 through 1977^{1/} forecasts a growth rate in current dollars of 6.5 percent (1975), 12.4 percent (1976) and 12.2 percent (1977). In constant 1977 dollars the growth rate is, minus .02 percent (1975), 3.4 percent (1976), and 6.0 percent (1977).

National R&D expenditures for 1975 are estimated as \$34.3 billion^{2/} which is 2.29 percent of the GNP.

Projections for R&D expenditures for FY 1976 and 1977^{3/} consider the increased Federal R&D funding of \$2.3 billion in FY 1976 and an additional \$2.4 billion in FY 1977 over FY 1976. Non-Federal R&D expenditures were projected to increase at a lower rate than the GNP growth based on selected readings on research and development ^{4/}.

The relationship of the R&D expenditures as a percent of the GNP in FY 1975 is estimated as 2.29 percent, for FY 1976 as 2.20 percent and FY 1977 as 2.11 percent.

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^{1/} The Budget of the U.S. Government, FY 1977.

^{2/} Federal Funds for Research, Development, and Other Scientific Activities FY 64, 75 and 76, NSF 75-334, Volume XXIV, Dec. 1975. p. 5 of Introduction.

^{3/} Special Analyses, Budget of the U.S. Government, FY 1977. p. 276.

^{4/} Selected Readings on Research and Development Expenditures and the National Economy. Prepared by the Subcommittee on Domestic and International Scientific Planning and Analysis of the Committee on Science and Technology, U.S. House of Representatives, Ninety-Fourth Congress, Second Session, Serial Z April 1976.

West Germany

Otmar Emminger, vice-chairman of the German central bank, expects Germany's real growth to climb by 3.5 percent to 5 percent in 1976. The decline in GNP was 4 percent.^{1/}

The increase in growth is mainly due to increased consumer demands rather than increased or improved technology.

Based on the above, the real GNP was estimated to be a decline of 4 percent in 1975, and increase of 4.1 percent in 1976 and 5 percent in 1977. R&D expenditures as a percent of the GNP was held constant at 2.41 percent for the three years.

^{1/} Business Week, December 8, 1975. pp. 40 - 41

U.S.S.R.

The traditional Soviet growth strategy relies mainly on two elements:

- rapid expansion of the labor force
 - investment of a very high proportion of national income in heavy capital-goods.^{1/}
- Unfinished construction projects (70 percent) in the U.S.S.R. Ninth Five Year Plan (1971 - 1975) will result in diverting funds from growth projects to complete construction.
 - Between 1971 and 1975, the working-age population grew by about 2.6 million each year. For 1976 - 80, the working age population will fall to 2.1 million and then virtually plummet to only 539 thousand per year between 1981 and 1985 (because of the loss of 15 million men in World War II).
 - With diminishing contributions from labor and capital inputs, Soviet growth will hinge from now on even more heavily on productivity improvements. But productivity growth is, in fact, getting worse rather than better. Unless this productivity slowdown is reversed, the future for Soviet industrial growth looks even more gloomy.
 - Leading Soviet politicians and planners prefer to use borrowed Western trade and technology as the way out of the productivity dilemma. Soviet trade in 1975 with capitalist nations is expected to exceed 50 percent of total trade for the first time.
 - GNP growth in the four years, 1971 - 1974 average out at an annual 4.4 percent growth.
 - R&D as a percent of the GNP in 1975 as derived from data obtained from Department of Commerce and the CIA was 3.14 percent.

Based on the above, the real GNP growth for 1975 was approximately 2 percent and is projected at an annual growth rate of 2 percent for 1976 and 1977. R&D expenditures as a percent of the GNP is projected as 3.0 percent for 1976 and 1977.

^{1/} Business Week, April 7, 1975. pp. 44 - 49.

Japan

- Japan's Economic Planning Agency indicated that the 1974 (FY ending 31 March 1975) real gross national product would decline from a low of 1.7 percent to high of 3.0 percent.^{1/}
- Keidanren, the Federation of Economic Organizations, foresees real growth of only 1 percent for 1975 (FY ending 31 March 1976), and no growth at all the following year if there are no new stimulants.^{2/}
- Based on the above, the following projections were made:
 - 1974 Decline in real GNP of 1.8 percent and no change in R&D expenditures with percent of R&D expenditures to GNP as 1.95 percent
 - 1975 Increase of real GNP of 1.0 percent with no change in R&D expenditures. Percent of R&D expenditures to GNP reduced to 1.93 percent
 - 1976 No growth in real GNP or R&D expenditures. Percent
/77 relationship remains at 1.93 percent.

^{1/} Business Week, March 31, 1975. p. 38

^{2/} Business Week, December 29, 1975. pp. 37 - 40

Economists bewail the impact of lower spending on growth and profits

Even if the apparent economic recovery takes a firm hold, some concerned economists are warning that the U.S. may face a serious slowdown in its long-term growth rate because of the protracted slump in spending for research and development.

Merton Peck of Yale calls it "the silent crisis"—not obvious like other national crises but nonetheless real. Harvard economist Zvi Griliches, one not given to hyperbole, says: "The slack

the next 10 years alone could reach \$100 billion, not counting the loss of improvement in the quality of life that cannot be measured in GNP dollars.

Moreover, productivity gains, which reduce unit costs, are a prime factor in combating long-term inflation. Thus, by scrimping on R&D, the nation is fighting the inflation battle with its right arm in a sling.

Losing ground fast. The slowdown in research spending has been dramatic. From 1953 to 1961, R&D expenditures, adjusted for inflation, increased at an average rate of 13.9% a year for government and 7.7% for nongovernment, according to the National Science Foundation. From 1961 to 1967, government-funded R&D increased 5.6% a year and private R&D 7.4%. But from 1967 to 1975, government spending rose a mere 1.3% a year, and nongovernment spending rose a mere 1.3% a year.

Recent studies confirm not only that R&D is a significant factor in the nation's growth but also that companies themselves are missing a good bet by not putting more of their dollars into R&D. The major findings:

- Organized R&D projects of the kind that are covered in company budgets account for about 40% of the total increase in U.S. productivity. This means that a dollar spent on R&D has a far greater impact on economic growth than a dollar invested in physical capital.

- Industry earns an average 30% rate of return per year on its R&D spending—about twice the return that companies get from their capital investments.

- On the average, the largest companies do not spend proportionately more or less than smaller companies, and their rate of return per dollar of R&D expenditure is also similar. Therefore, tinkering with the market structure of U.S. industry to spur R&D spending offers no hope of a payoff.

Three sources feed the stream of national economic growth: capital investments, increases in both the quantity and quality of the labor force, and improvements in technology. Although economists have long labored over the

have been as important to the economic growth of the U.S. as increases in capital and labor. Fully one-third of the measured growth in GNP has come from technological progress, they say.

The payoff. Technological progress stems from a variety of sources, including such informal ones as the amateur inventor pattering in his garage on weekends or the manager who gets a idea on how to organize the production line better. The major question is how much of this progress has resulted directly from organized R&D. Griliches' econometric findings put this contribution at 20% to 25%. And a recent study by Nestor E. Terleckyj of the National Planning Assn. conservatively estimates that in 1948-66 organized R&D was responsible for at least 33% of the improvement in technology. Considering that industry invests about 10 times as much in plant as in R&D, \$1 of R&D has almost four times the impact on growth that \$1 invested in plant and equipment has.

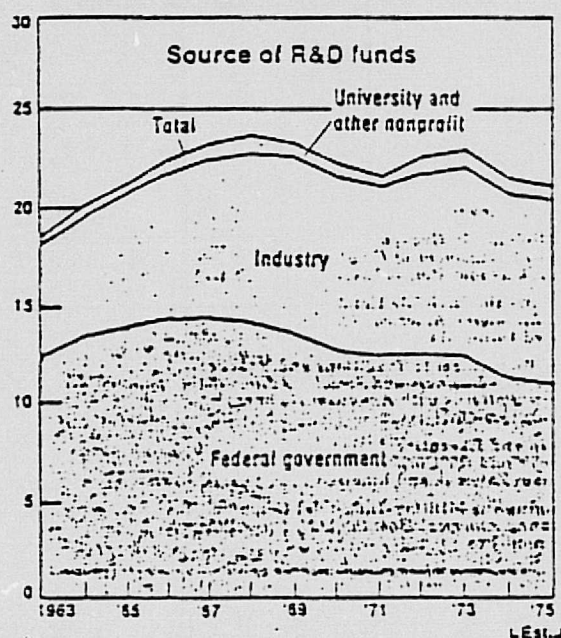
Spending on R&D has not only paid off in a big way for the country as a whole but has also produced high rates of return for the industries that do the spending. A paper by Griliches shows that in 1957-65 R&D produced an average annual 27% rate of return, based on the depreciated life of the expenditure. This, he says, is about twice the return on physical capital investments by the 383 companies in his sample.

Using a different set of data, Terleckyj finds a direct productivity return of about 30% a year on R&D in manufacturing industries in 1948-66. Moreover, he finds, some industries that do little of their own R&D but buy from R&D-intensive industries achieved productivity gains of 30% per year. For example, airlines benefit from the R&D done by the airplane industry.

The findings of Griliches and Terleckyj apply only till the mid-1960s, the latest years for which detailed data are available. But a study by Edwin Mansfield of the Wharton School seems to indicate that high rates of return persisted into the 1970s. Mansfield used a sample of 17 run-of-the-mill innovations, ranging from a metal process introduced in the late 1950s to a door control mechanism marketed in the early 1970s. He shows an average annual rate of return of 25% to the innovating company, after adjustment for unsuccessful R&D efforts, and a return of well over 50% to other users as a whole.

Why the slump? Given the high rates of return on R&D, economists are hard-pressed to explain why industry spending has lost its historically robust growth. Industry R&D amounted to 1.5% of total sales in 1957, peaked at

The prolonged slump in R&D



Billions of 1957 dollars

Data: National Science Foundation, BW

growth of the past seven years in research and development spending will come home to roost."

Economists in this group maintain that the slowdown in long-term growth has already been set in motion by the slump in R&D spending since the late 1960s (chart). They have no pat solutions to the problem, and their new findings raise almost as many questions as they answer. But their message is clear: unless the nation steps up

investment in developing and marketing improved processes and products, the U.S. economy is doomed to grow more slowly in the 1970s and 1980s than it did in the 1960s. The potential loss in gross national product in



Mansfield: "R&D isn't worth anything alone. It has got to be coupled with the market."

23% in 1969, and has now fallen below 2%.

Some businessmen contend that increased government regulation of industry has put a crimp in private R&D. But Terleckyj argues that it should only open vistas for new and better products and would not have an overall negative impact. Some critics suggest that the oligopolistic market structure of U.S. industry is the cause. But economists who have analyzed the relationship between company size and technological progress deny this claim.

There are two conflicting views of the impact of big companies on innovation. One theory, first formulated by the late Joseph Schumpeter and eloquently elaborated upon by John Kenneth Galbraith, holds that R&D is carried out much more productively by very large companies. To foster innovation, this theory would call for relaxation of the antitrust laws. In total contrast, some economists and most consumer advocates maintain that large companies stifle innovation, so antitrust laws should be enforced more vigorously.

The overwhelming evidence is that neither theory fits the facts. "For practically all industries," Wharton's Mansfield says, "the data indicate that very big firms do not carry out more innovation relative to their size than do smaller firms." Instead, economists find a threshold effect. Explains Mansfield: "In order to do much research and development, a firm must be of a certain minimum size—which, of course, will vary by industry. Beyond that, innovation seems to be proportional to size." He does note exceptions, though. For example, Du Pont spends more on R&D, relative to its size, than smaller chemical companies do.

... productivity out of an R&D dollar than somewhat smaller companies get. Mansfield adds, but this disadvantage is offset by their ability to do a superior marketing job. He says: "Small and large firms should be looked at as complements to each other. You need the small firm's flexibility to move quickly, especially in the initial stages

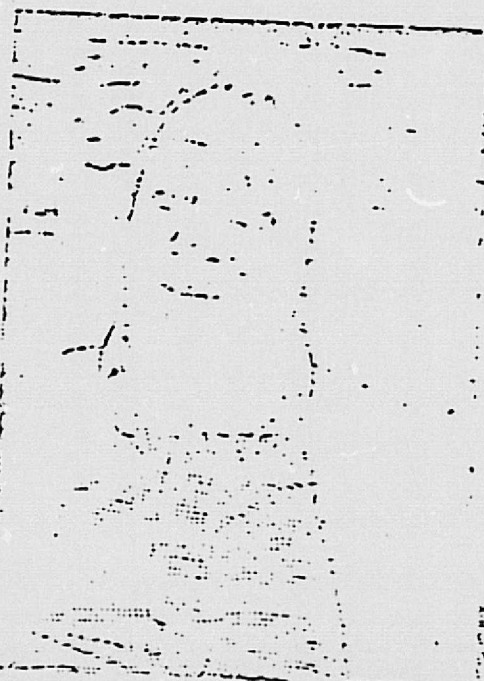
Companies are missing a good bet by not putting more money into R&D

of innovation, and you need the very large firms with their huge capital resources, large numbers of researchers, and marketing knowhow."

How to cash in. "R&D isn't worth anything alone," Mansfield maintains. "It has got to be coupled with the market. The innovative firms are not necessarily the ones that produce the best technical output but the ones that know what is marketable."

Economists who agree cite as an extreme case the Soviet Union's problems in improving productivity through R&D. "They keep spending tons of money on R&D, but they don't get much out of it," says a government economist who specializes in Soviet affairs. "The Soviets are right at the frontiers of research in the lab. It's getting from the lab to metal-bending and into production that is the trick."

Charlotte Schroeder of the University of Virginia, an expert on the planned economies, notes that the Russians are turning out engineers and scientists by the drove. But because of the emphasis on today's production, managers have little incentive to shut down for retooling and, thus, are not receptive to new ideas. "The research-



Griliches: "The stock growth of the past seven years."

... production people are different wavelengths," she says.

Resistance to innovation is not confined to planned economies, Mansfield finds. In a survey of the R&D executives of 20 major chemical, drug, and electronics companies in the U.S., he found an opinion that the success rate of innovation would have been boosted by 50% if the R&D results had been fully and properly exploited by their companies' manufacturing and marketing people. To confirm this evaluation, Mansfield put the same set of questions to non-R&D executives. Their estimate turned out to be even higher than that of the R&D managers.

Incentives. While economists agree that companies should invest more heavily in R&D and should improve their output from it, by no means all of them advocate that government should provide special tax incentives. "Since R&D really is investment, there's already a tax benefit because companies can write it all off," says William Fellner, of the American Enterprise Institute. And Yale's Milton Peck says: "I'm against government incentives. The best thing to get private R&D moving is get this economy off its bottom."

But Mansfield disagrees. "We need a general incentive," he suggests. "Let's explore tax incentives carefully." Edward F. Denison of the Brookings Institution, a pioneer in the study of economic growth, says: "I have always been against tax incentives for R&D. But after seeing Mansfield's work on the rate of return, I'm reconsidering my position."

Although Fellner is against tax incentives, he favors more federal funds for R&D, especially where the risks for private industry are enormous, as in energy development. In the 1977 budget, federal funds for R&D increased only 10% in inflation-bloated dollars, and Fellner notes that real R&D will rise less than real GNP. "I would not try to save on the R&D budget," he says.

Griliches believes that more federal dollars should be going into the universities, where he says the nation has a high-class scientific establishment that is "now underutilized and minuscule." The low rate of utilization, he concedes, is partly the universities' own fault. "They expanded, thinking that government funds would be flowing forever," he says. Still, he says, university labs represent an underutilized resource that should be put to work.

Like Fellner, Mansfield argues for more federal R&D funds, but he also does not advocate opening all the money taps. "I'm not for throwing a wad of money into machine tool research, for instance," he says. "What we do need is a concerted research effort to determine just what government R&D funds should be going to."

TABLE 7.—ALTERNATIVE FORECASTS OF PHYSICS PH.D.'S 1970-80

Years	Office of Education	Carter	NAS-NRC	Model A	Model B
1969-70*	1300	1300	1300	1300	1300
1974-75	2153	1853	2153	1134	1189
1979-80	2492	2654	3350	711	786

Source: Office of Education, Carter, NAS-NRC from Carter; Models A and B, from the recursive model of Tables 4 and 5, as described in the text.

* The various projections use different base year numbers of Ph.D.s due to differences in the source of data. National Academy of Science-National Research Council (NAS-NRC) data differ somewhat from those of the Office of Education. I have set the base year number as 1300 and made projections on the basis of implicit percentage increases in the actual forecasts.

entrants will ameliorate physics market problems; according to the standard calculations, increases in supply will exacerbate the potential imbalance of the 1980's due to the likely fall in demand for faculty. While different changes in exogenous variables such as a sudden sharp increase in federal R&D spending on energy would significantly invalidate our forecasts, it is evident from Table 7 that economic responsiveness has a first-order effect on the market and should be taken into account in manpower analysis.

III. Summary

The principal findings of this study can be summarized briefly:

1) The number of physics students has varied greatly in the postwar period, declining in the recent collapse of the science market after a decade of rapid increase. These changes result from economic responses to salary or job opportunity incentives, with fairly large elasticities of supply for physics salaries ranging from about unity in the short run to 3 or 4 in the long run at the graduate level, and from 2 in the short run to 4 in the long run for B.S. recipients.

2) Salaries of physicists have fluctuated significantly relative to other wages and salaries, rising in the post-Sputnik

boom period and falling rapidly in the late 1960's and early 1970's. The bulk of the change in salaries can be attributed to R&D expenditures and the R&D policies of the federal government, with changes in supply having a smaller, though significant, effect.

3) Developments in the physics market, as in several other high level labor markets, appears to be well described by a simple recursive model which exploits the time delay in supply due to lengthy training programs. As a result of the recursive structure, large numbers of physics graduates create a market setting likely to reduce enrollments and future degrees in the field in accord with the cobweb scenario.

While the market still faces the major shock of a demographic-induced decline in demand for faculty in the 1980's, supply and salary adjustments will provide an important buffer to the decline.

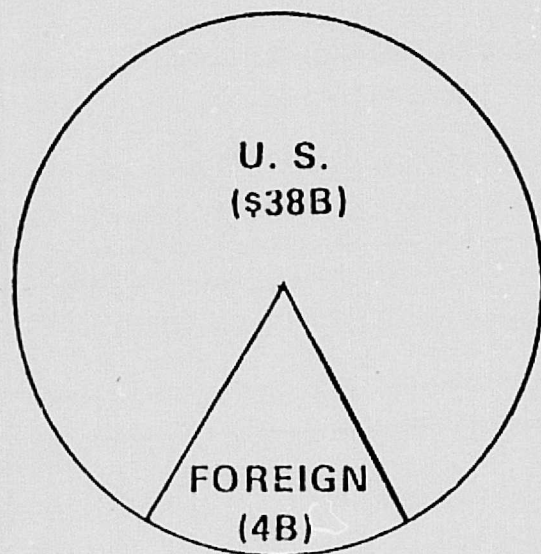
REFERENCES

- K. Arrow and W. Capron, "Dynamic Shortages and Price Rises: The Engineer-Scientist Case," *Quart. J. Econ.*, May 1959, 71, 192-305.

WORLD TRANSPORT MARKET

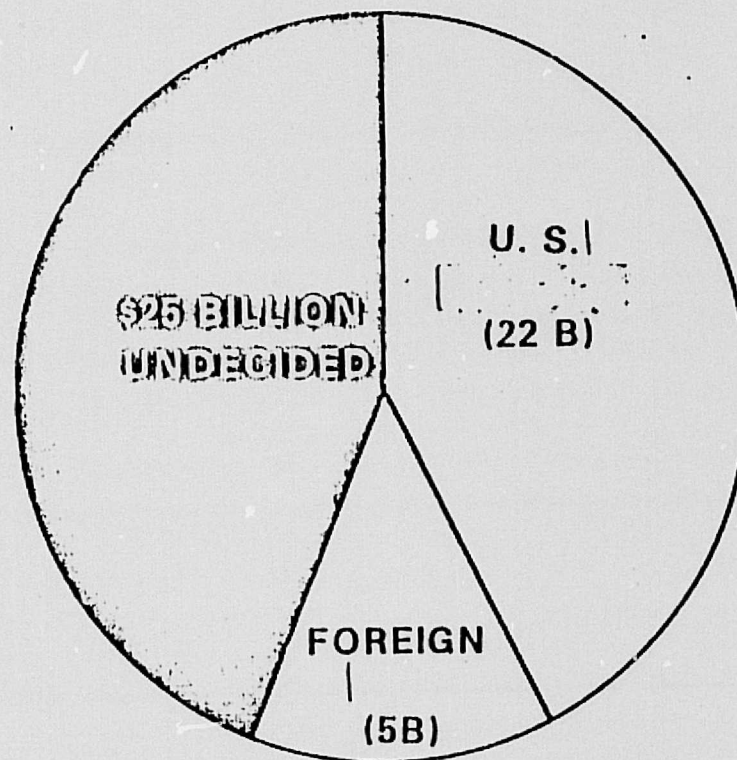
WORLD TRANSPORT AIRCRAFT MARKET

PAST DECADE



\$42 BILLION MARKET

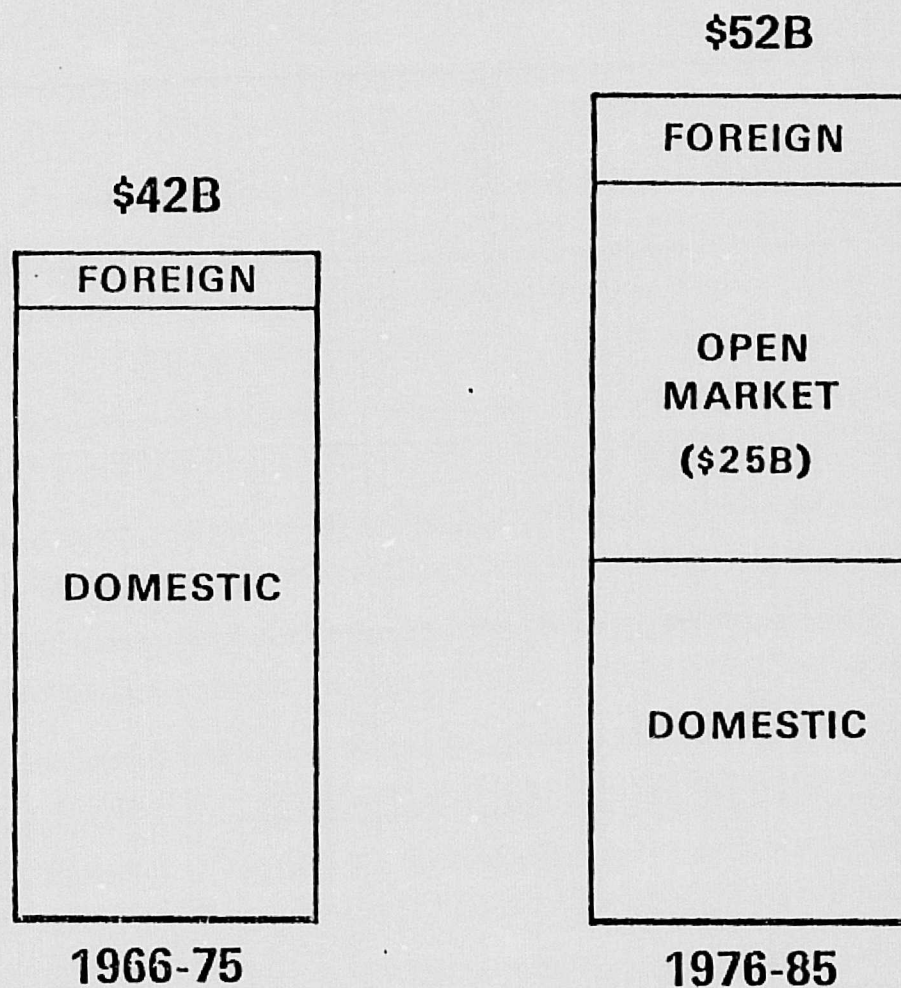
NEXT DECADE



\$52 BILLION MARKET

▶ U. S. COMPETITIVE POSTURE AT STAKE

WORLD AVIATION MARKET



► U. S. COMPETITIVE POSTURE AT STAKE

REFERENCES

1. . Future of Aviation Naional Transportation System Subcommittee on
Aviation and Transportation R&D, *Steiner Testimony*

A large share of the aircraft required by the U.S. air transportation system are of medium and even small size. We have mentioned that there are no modern medium size aircraft available from U.S. manufacturers due to the inability of the U.S. airlines to start such programs. We have also mentioned that the only medium size aircraft available is the French/German A300B and the only small size high technology programs seriously contemplated are European. We were asked last year by the U.S. government if we would estimate the magnitude of the U.S. manufacturing program which was thus at risk. The result was the curve shown.

The curve is in 1975 constant dollars and traces annual delivery dollars in billions from the year 1950 through the year 1985. It shows the expansion of the industry in the years between 1960 and 1970. It also shows the slump of 1972 and the slump we have been in.

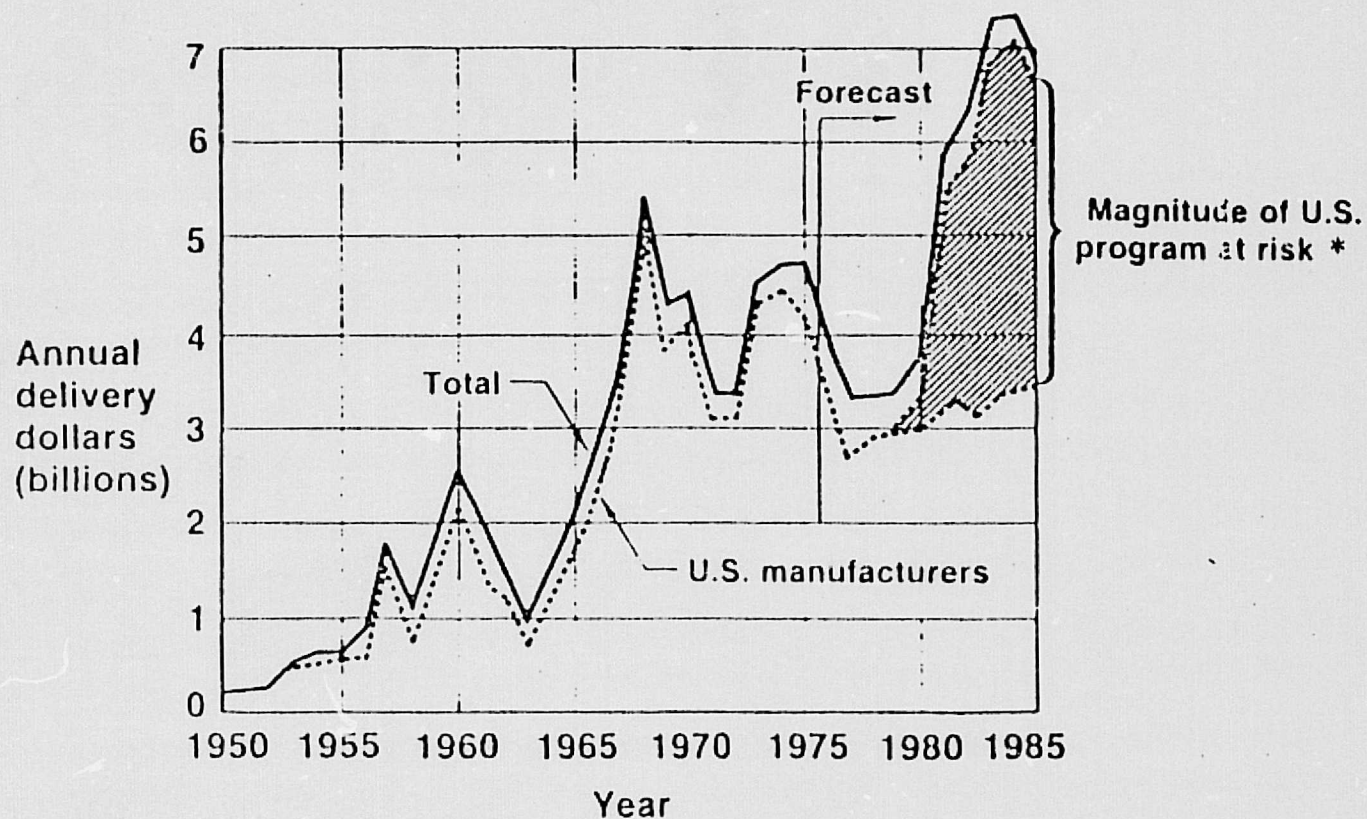
We have also mentioned the deferred buying syndrome due to the condition of the U.S. airlines. This deferred buying syndrome, while the system is expanding and some of its aircraft are becoming obsolete, produces a large delivery requirement between the years 1980 and 1985.

It should be remembered that orders for commercial airplanes have to be placed one and one-half years ahead of deliveries for an existing type and around four years ahead of deliveries for a new type.

The dashed line below the solid one in the graph indicates the amount of the total world market fulfilled by U.S. manufacturers. If new U.S. programs could be started, it is estimated that the dashed line would continue to the top of the shaded area. If new, or major derivative, U.S. programs cannot be started, it is estimated that U.S. manufacturers could stand to lose approximately one-half of the total world market during the years contemplated, if foreign producers could support the production rates required to fulfill this demand on a timely basis.

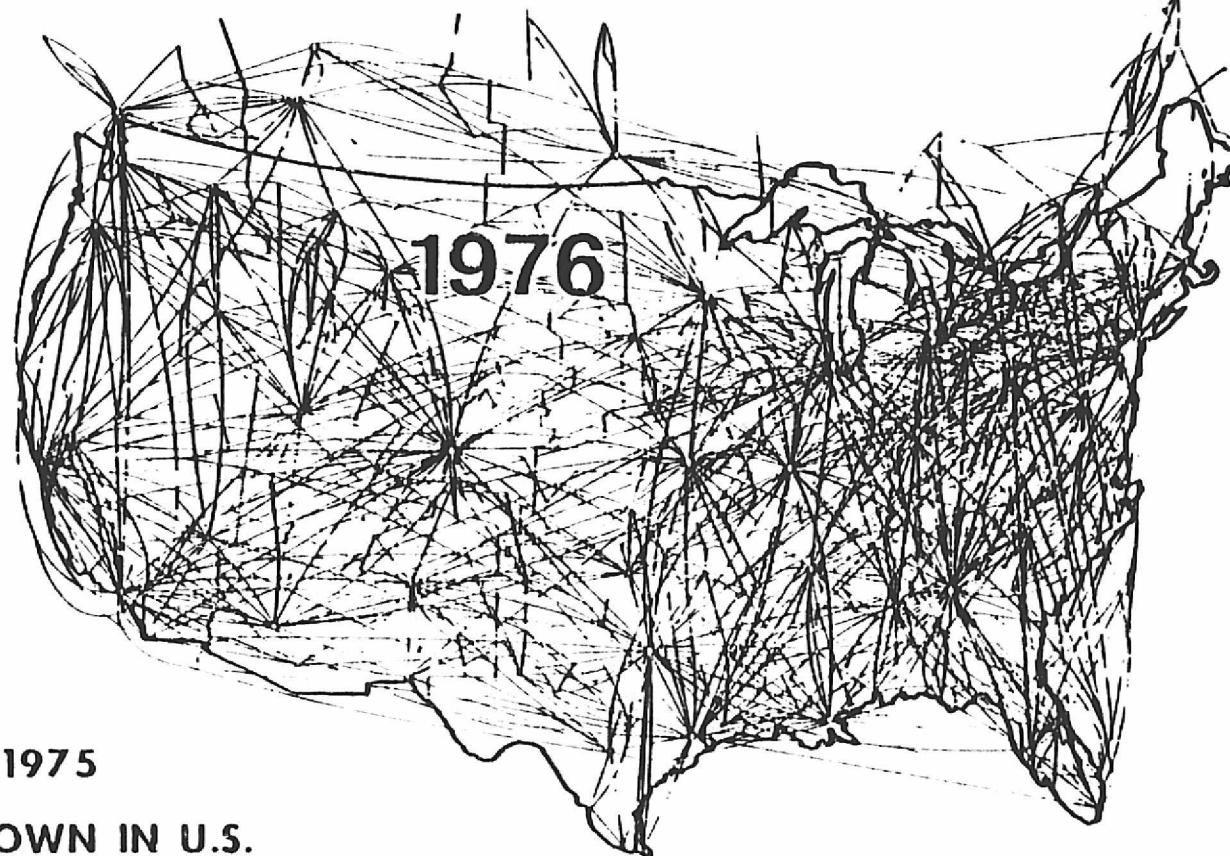
World Commercial Aircraft Annual Deliveries

(1975 Constant Dollars)



Note: Excludes USSR, Peoples Republic of China, and non-ICAO countries

* Forecast for U.S. new and derivative airplanes.



944,000 JOBS

\$32 BILLION IN GNP 1975

2.5 BILLION MILES FLOWN IN U.S.

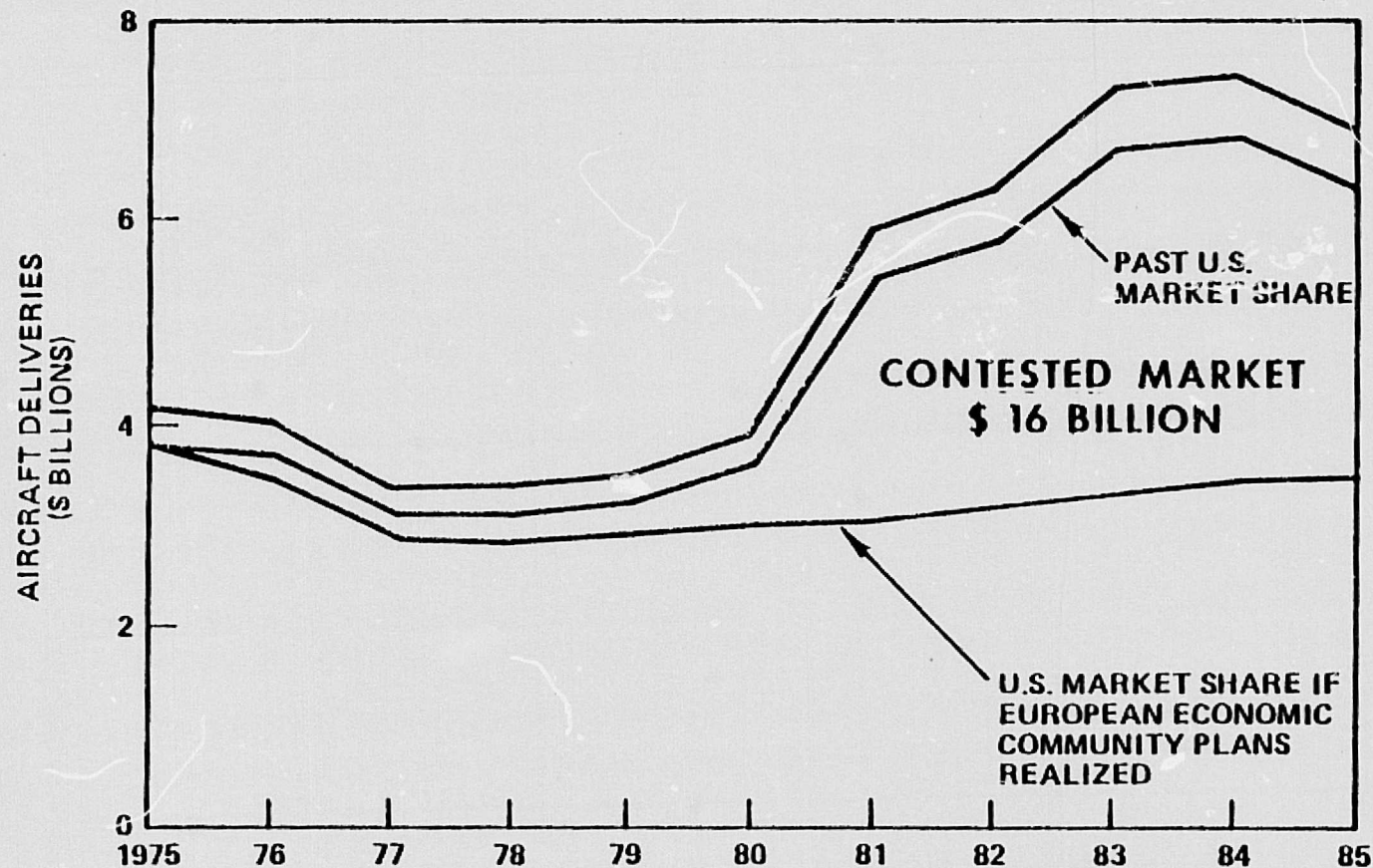
U.S. BUILDS 85% OF FREE WORLD CIVIL AIRCRAFT

\$6 BILLION FAVORABLE TRADE BALANCE FROM CIVIL AIRCRAFT SALES

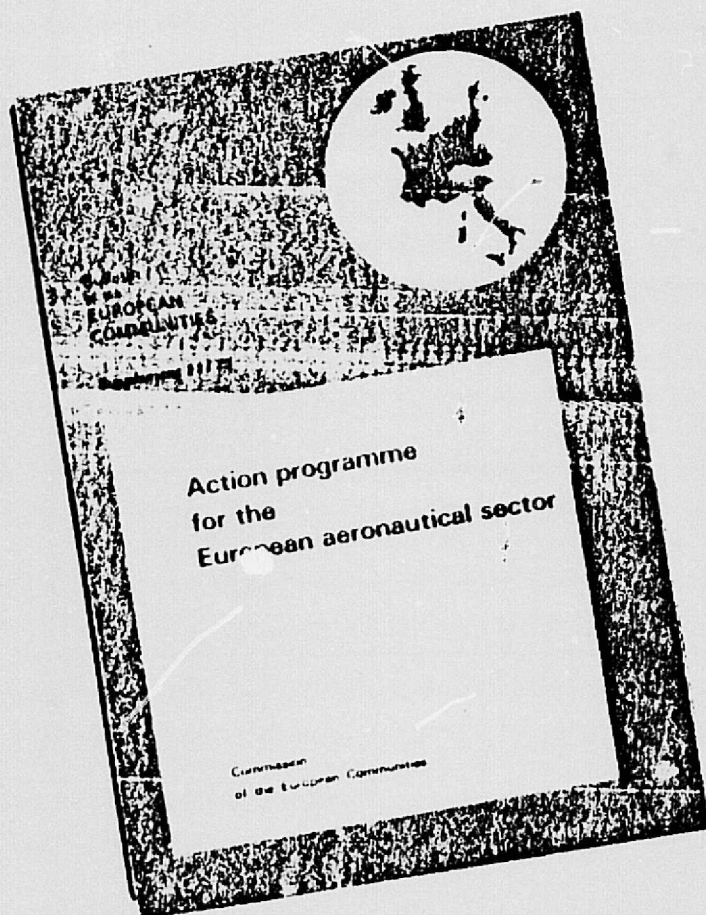
**AIR TRANSPORTATION IS IMPORTANT
TO U.S. ECONOMY**

WORLD TRANSPORT AIRCRAFT MARKET

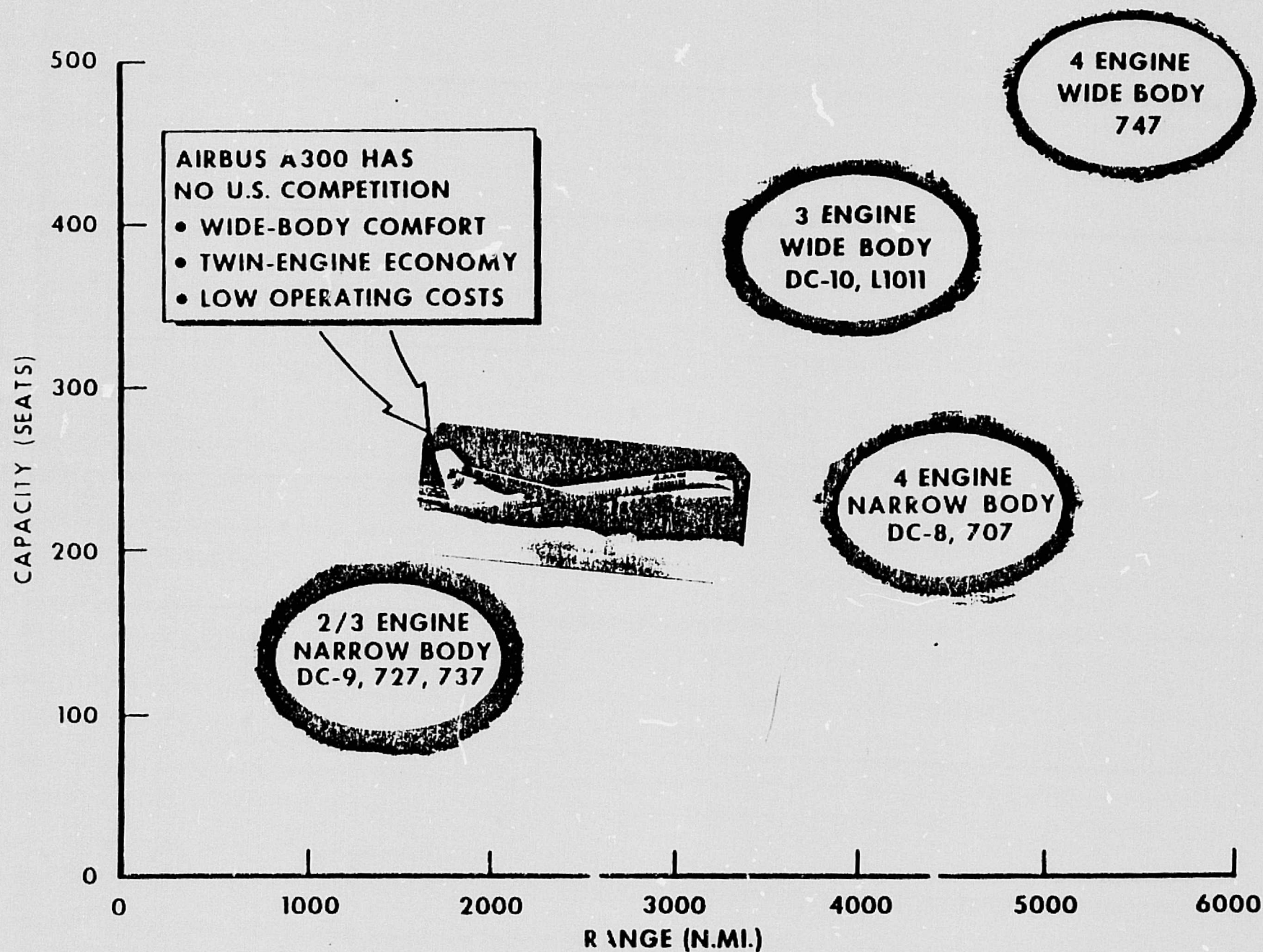
TOTAL WORLD MARKET — 10 YEARS — \$ 52 BILLION



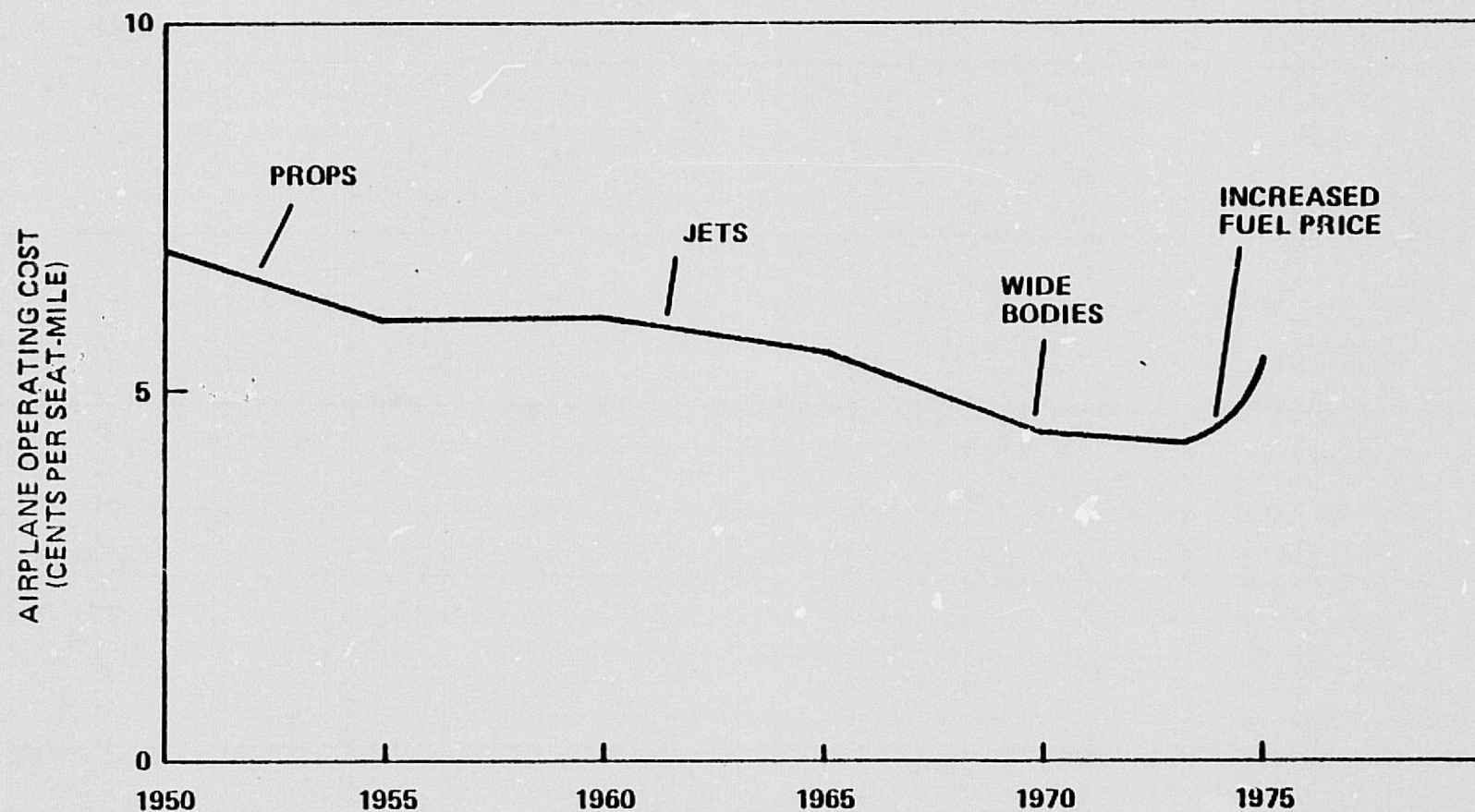
THERE WILL BE A LARGE WORLD DEMAND FOR
CIVIL AIRCRAFT



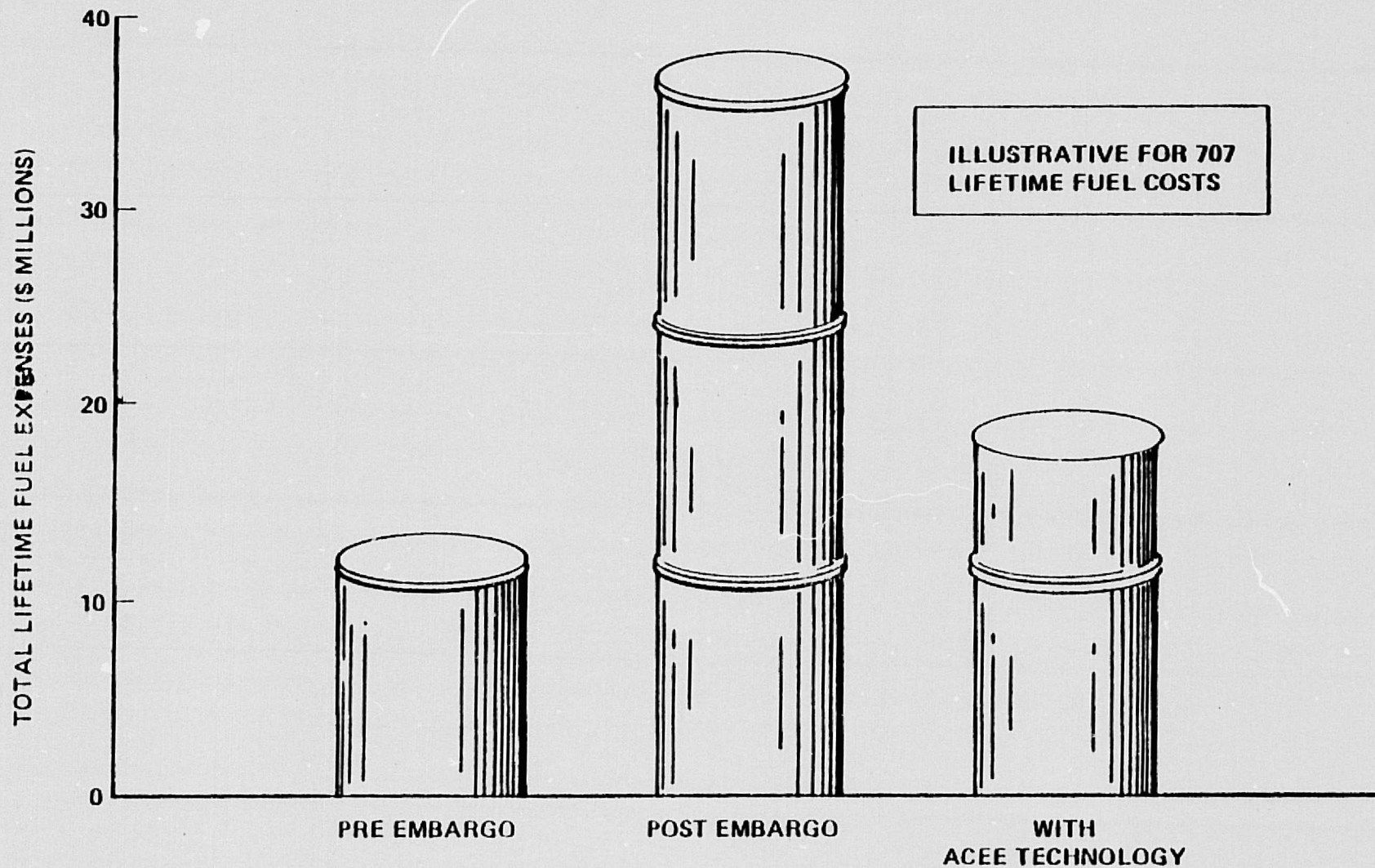
- RESEARCH AND TECHNOLOGY PROGRAM JOINTLY FUNDED BY EUROPEAN MEMBERS
- CREATE EXPORT CREDIT SYSTEM – EUROPEAN EXPORT BANK
- EXPANSION OF EUROPEAN AIR TRANSPORT SYSTEM
- JOINT EUROPEAN MILITARY AIRCRAFT PROCUREMENT
 - STANDARDIZE EQUIPMENT
 - JOINT PLANNING OF FUTURE MILITARY NEEDS
- UNIFIED PROGRAM FOR EUROPEAN INDUSTRY DEVELOPMENT AND MANUFACTURE OF TRANSPORT AIRCRAFT



EUROPE FILLS GAP IN AIR TRANSPORT MARKET

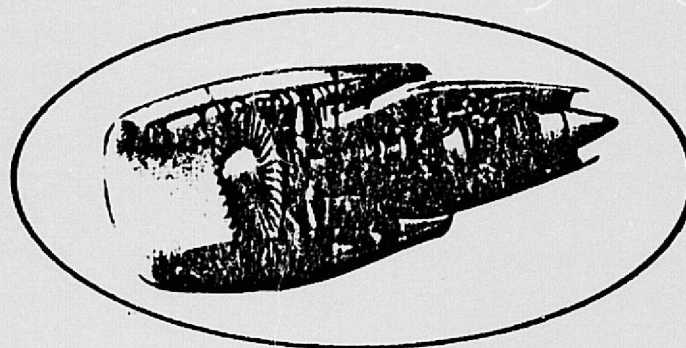


**TECHNOLOGY ADVANCES HAVE
DECREASED COST OF AIR TRAVEL**

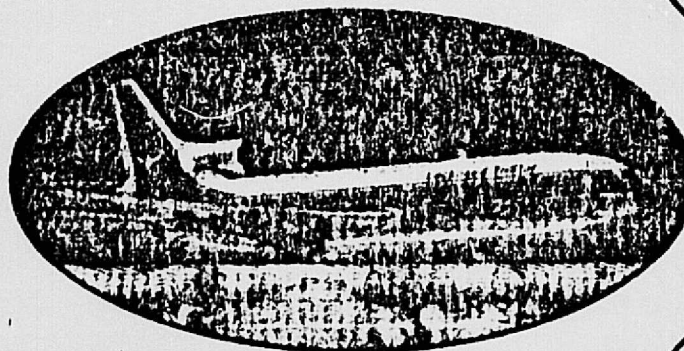


**ACEE TECHNOLOGIES REDUCE IMPACT OF
FUEL PRICE INCREASE**

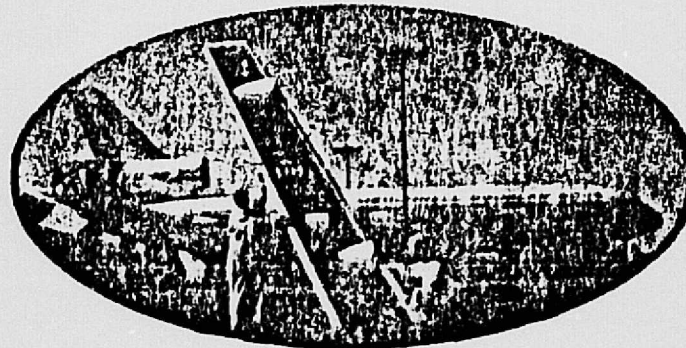
**ENGINE
COMPONENT
IMPROVEMENTS**



**ADVANCED
AERODYNAMICS
FLIGHT
EXPERIMENTS**



**COMPOSITE
SECONDARY
STRUCTURES**



**MODIFIED AIRCRAFT
OF THE EARLY 1980'S**

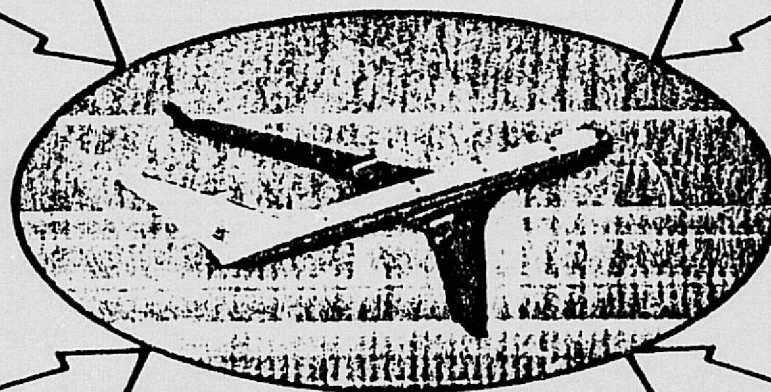
**ACEE TECHNOLOGY CONTRIBUTIONS TO MODIFIED AIRCRAFT
OF THE EARLY 1980'S**

**ADVANCED
AERODYNAMICS**

**ADVANCED
CONTROL SYSTEMS**

**LIGHT WEIGHT,
LOW COST
COMPOSITE STRUCTURES**

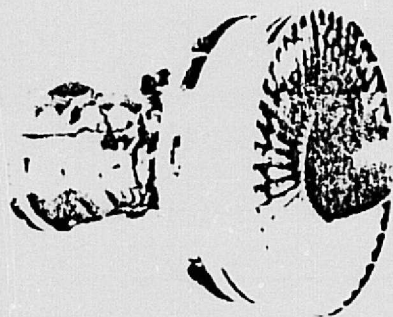
**ENERGY EFFICIENT
ENGINES**



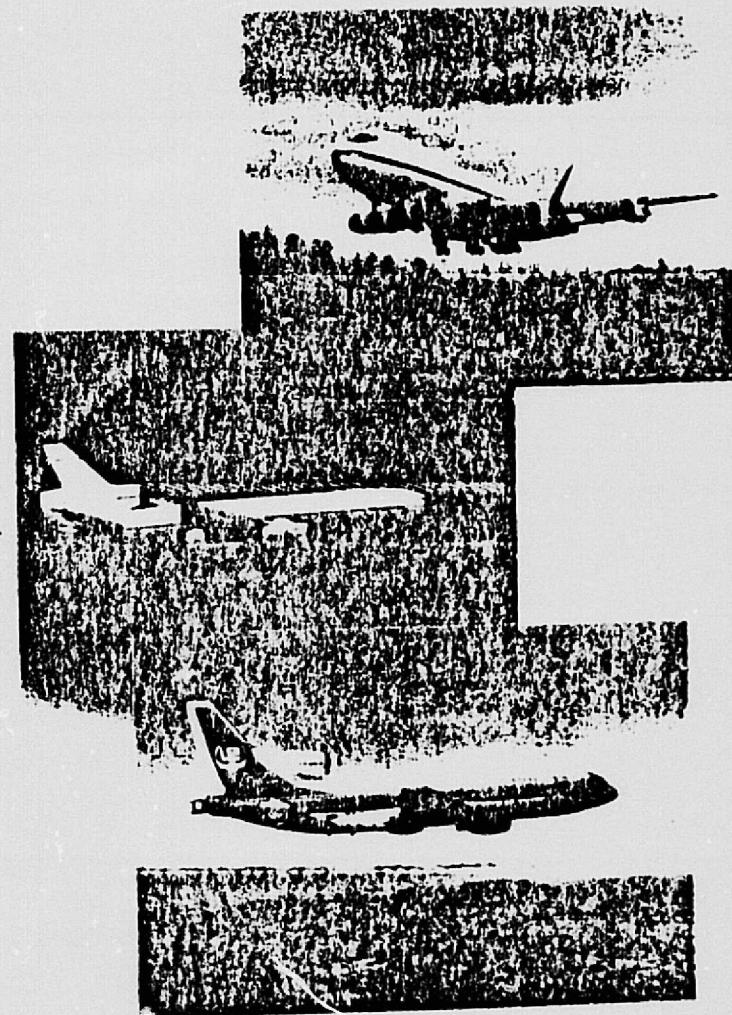
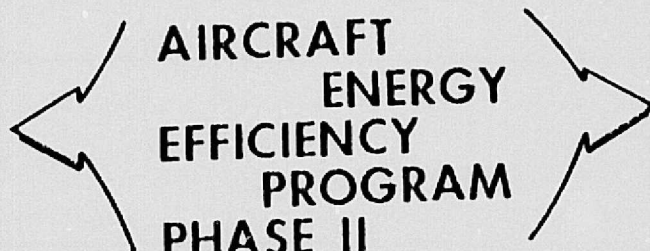
**ACEE TECHNOLOGY CONTRIBUTIONS TO
ALL-NEW AIRCRAFT OF THE LATE 1980'S**

FLIGHT TESTS OF MODIFIED AIRCRAFT

GROUND TEST ENERGY
EFFICIENT ENGINE

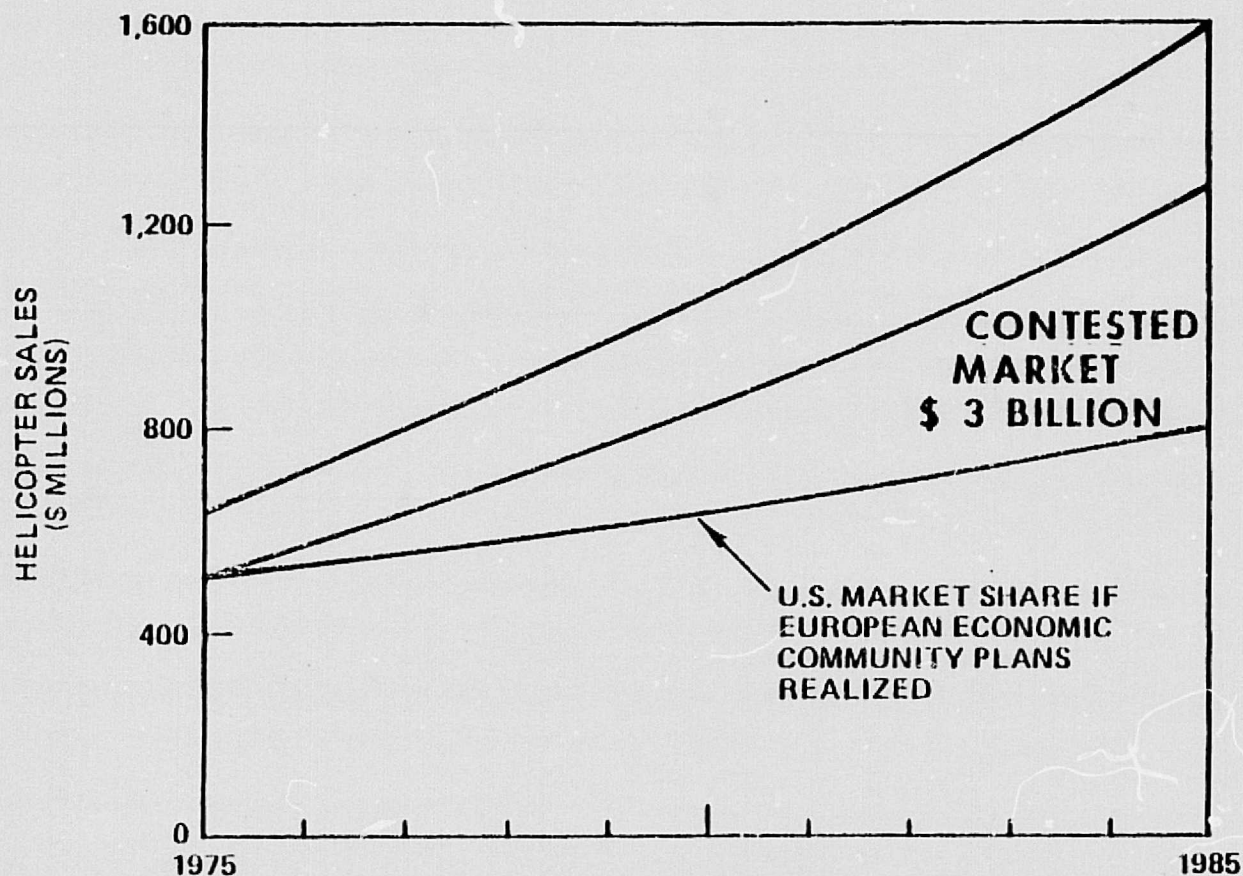


AIRCRAFT
ENERGY
EFFICIENCY
PROGRAM
PHASE II



WORLD CIVIL HELICOPTER MARKET

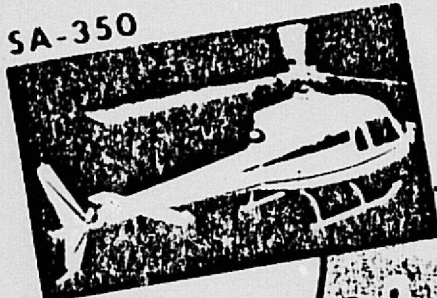
TOTAL WORLD MARKET — 10 YEARS — \$ 12 BILLION



WORLD MARKET FOR CIVIL HELICOPTERS IS
GROWING RAPIDLY

FOREIGN DEVELOPMENTS
— GOVERNMENT SUPPORTED

SA-350



SA-360

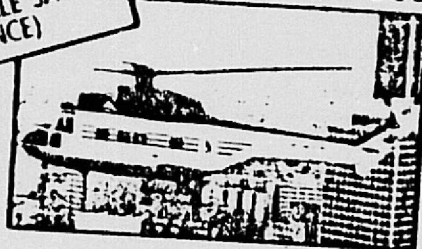


SA-366



AEROSPATIALE SA-366
(FRANCE)

SA-330



AEROSPATIALE
ALL IN FLIGHT STATUS



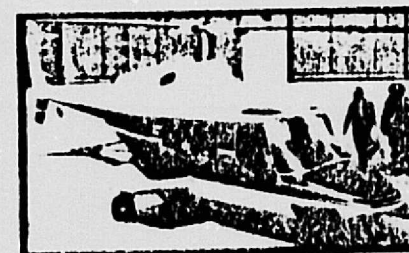
AGUSTA
IN FLIGHT STATUS

U.S. DEVELOPMENTS
— COMPANY FINANCED



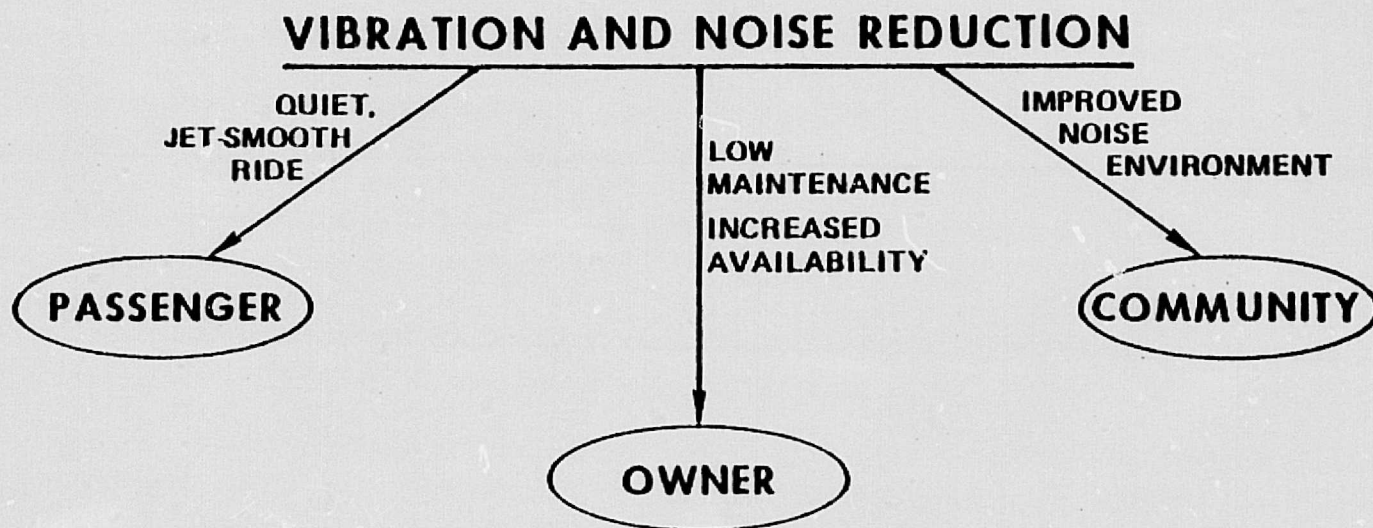
SIKORSKY S-76
FIRST FLIGHT 6/77

2000
UNITS/YEAR
MARKET

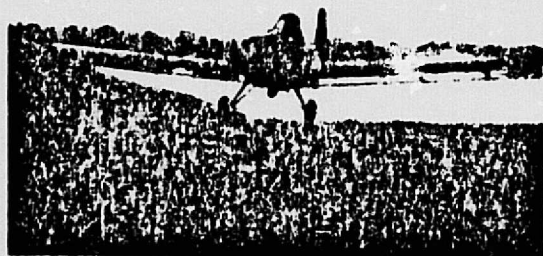


BELL 222
FIRST FLIGHT 7/76

WORLD HELICOPTER COMPETITION



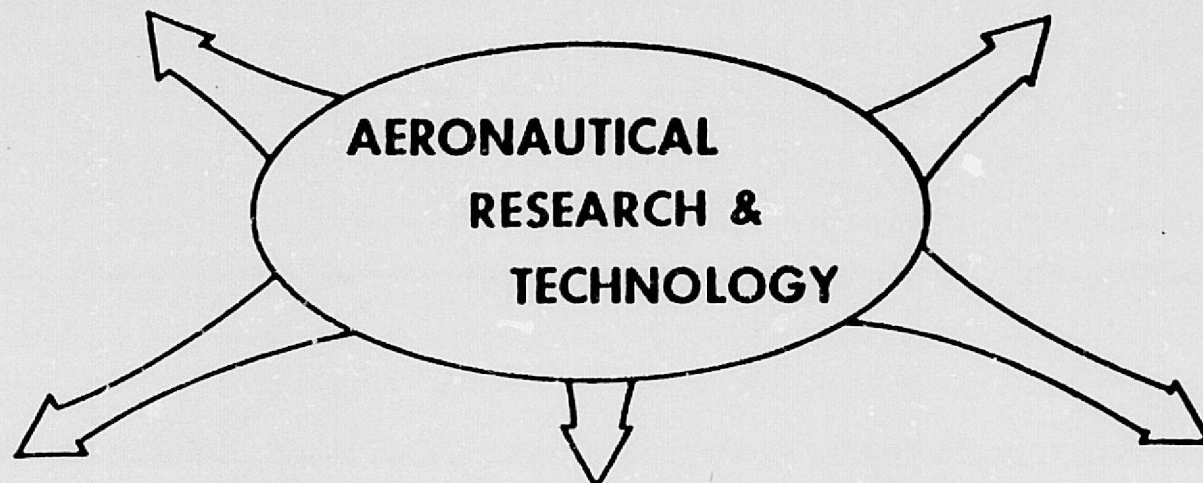
**TECHNOLOGY ADVANCES CAN MAKE
BIG IMPROVEMENTS IN HELICOPTERS**



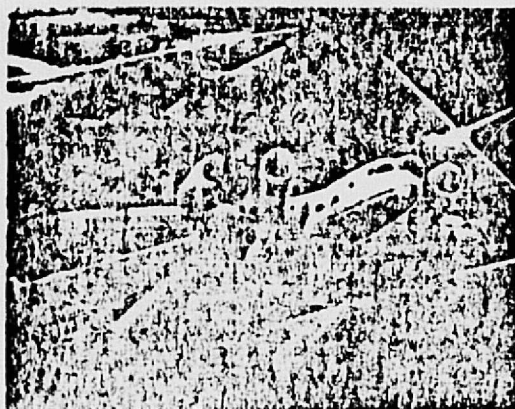
**IMPROVED AERIAL
APPLICATION METHODS**



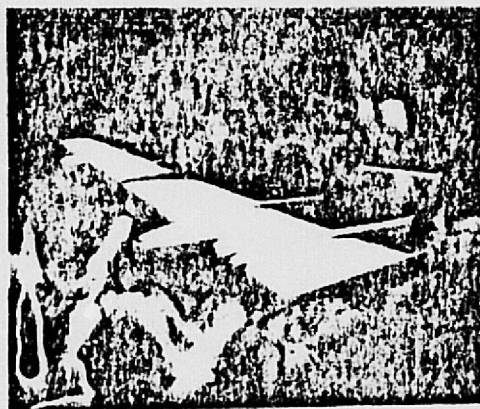
**ADVANCED
SUPERSONIC TRANSPORT**



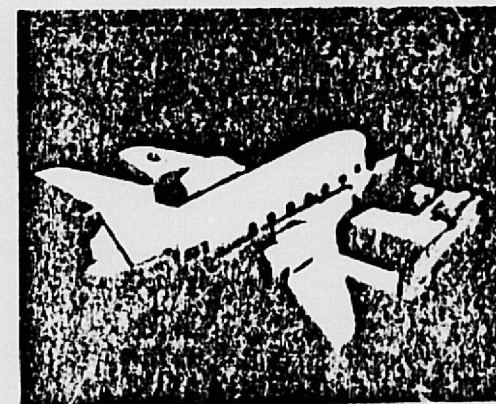
**ECONOMICAL
SHORT HAUL TRANSPORT**



**ADVANCED
CARGO TRANSPORT**



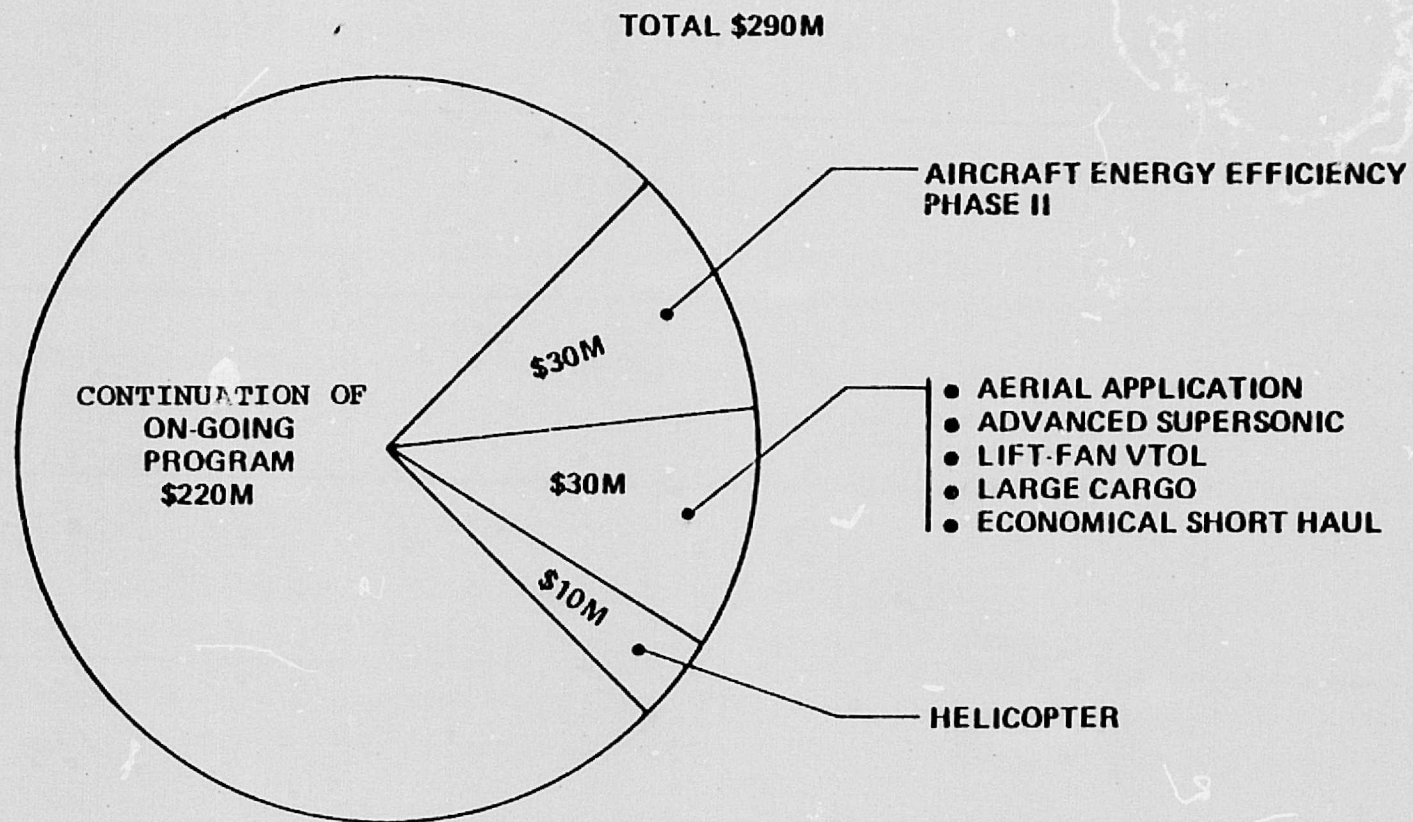
**LIFT
FAN AIRPLANE**



AVIATION GROWTH 1940-2000



PRODUCTIVITY ORIGINALLY PATENTED



FY 1978 AERONAUTICS R&D BUDGET

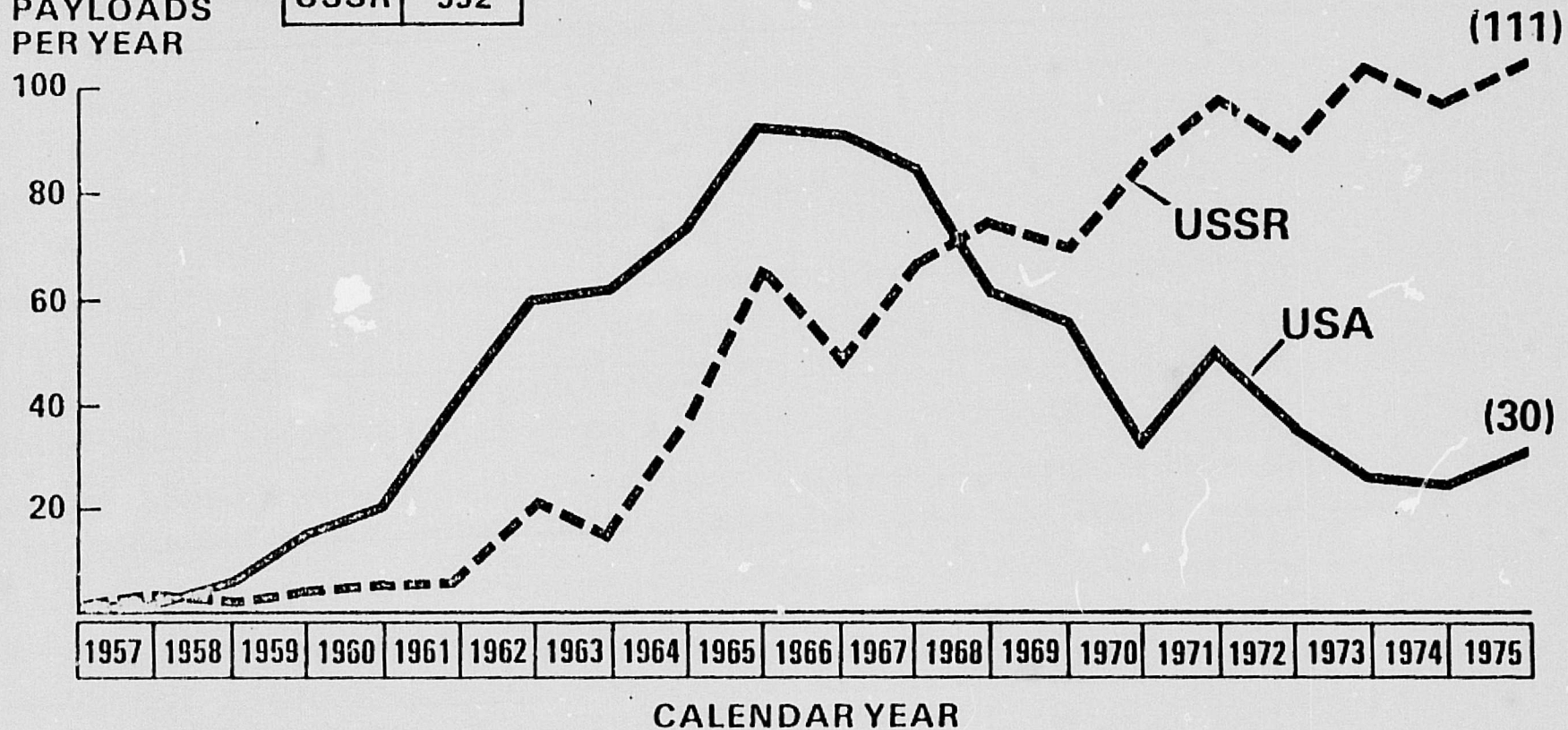
SPACE PAYLOADS

SPACE PAYLOADS

NUMBER OF
PAYLOADS
PER YEAR

USA	863
USSR	992

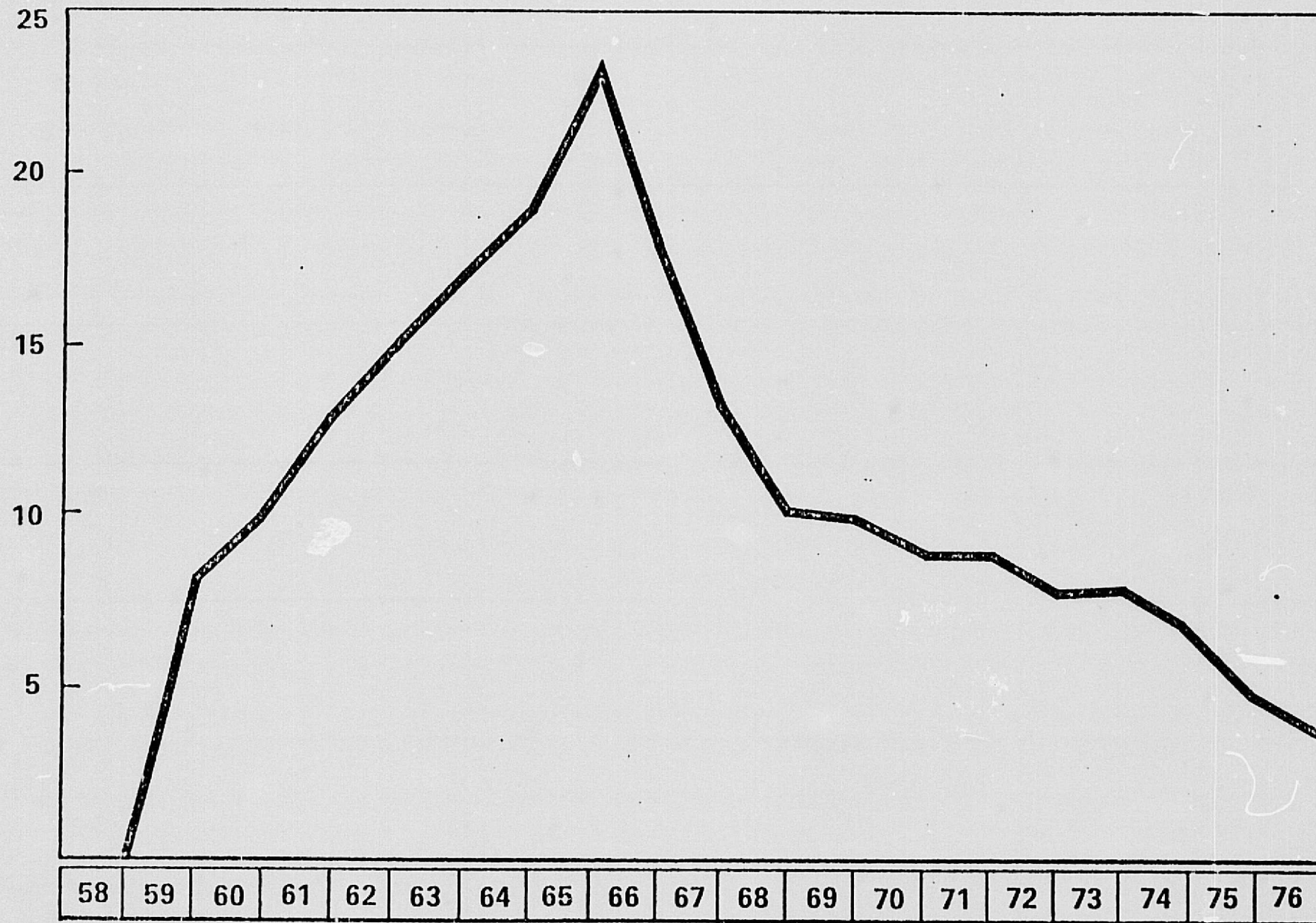
AS OF 31 DECEMBER 1975



► U. S. SPACE LEAD IS BEING OVERTAKEN

NASA PAYLOAD TREND

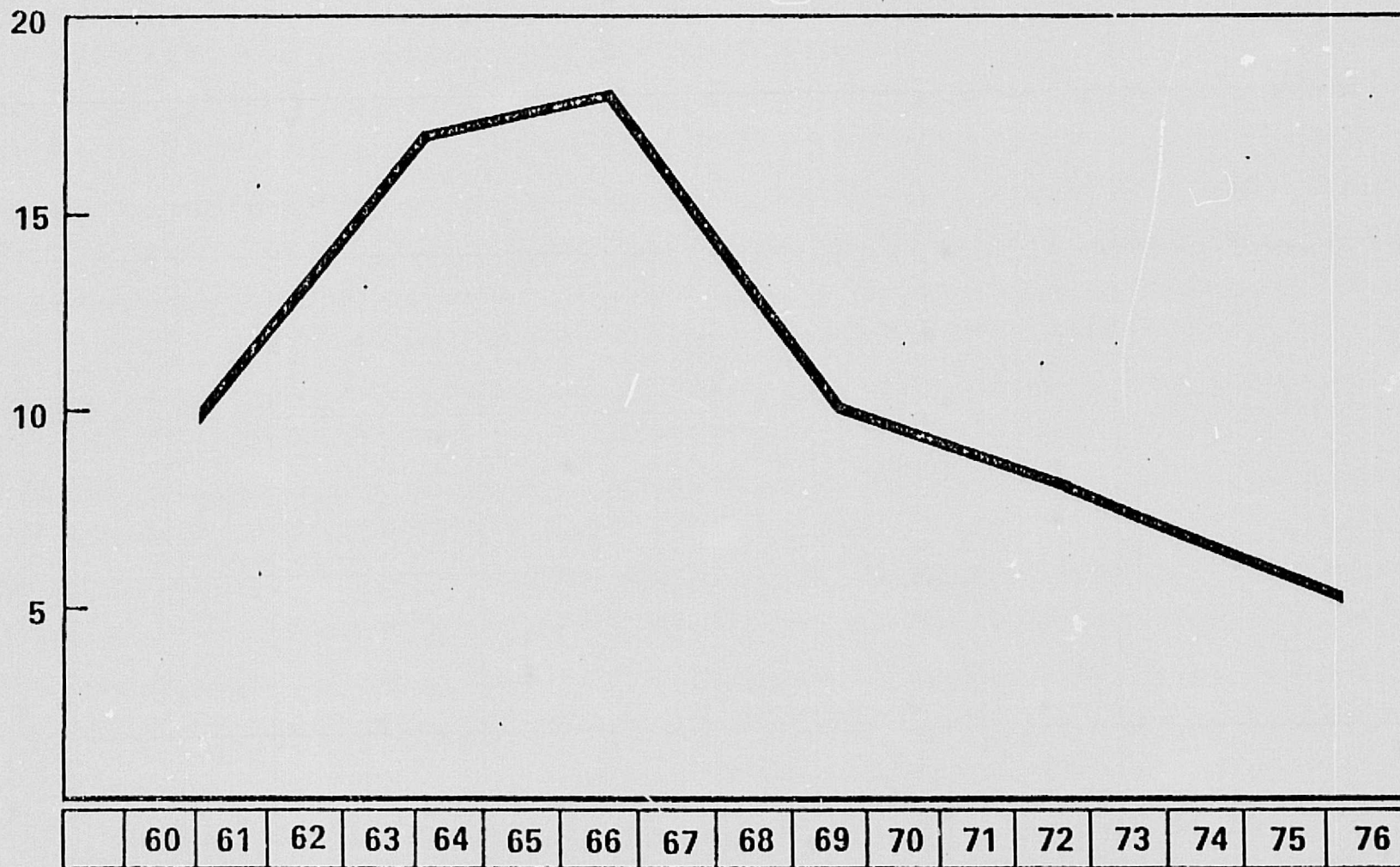
PAYLOADS
PER YEAR
(3 YR. AVERAGES)



▶ ERODING CIVIL SPACE ACTIVITY

NASA PAYLOAD TREND

PAYLOADS
PER YEAR
(3 YR. AVERAGES)



▶ ERODING CIVIL SPACE ACTIVITY

NASA HQ RX76-3318 (1)
5-20-76

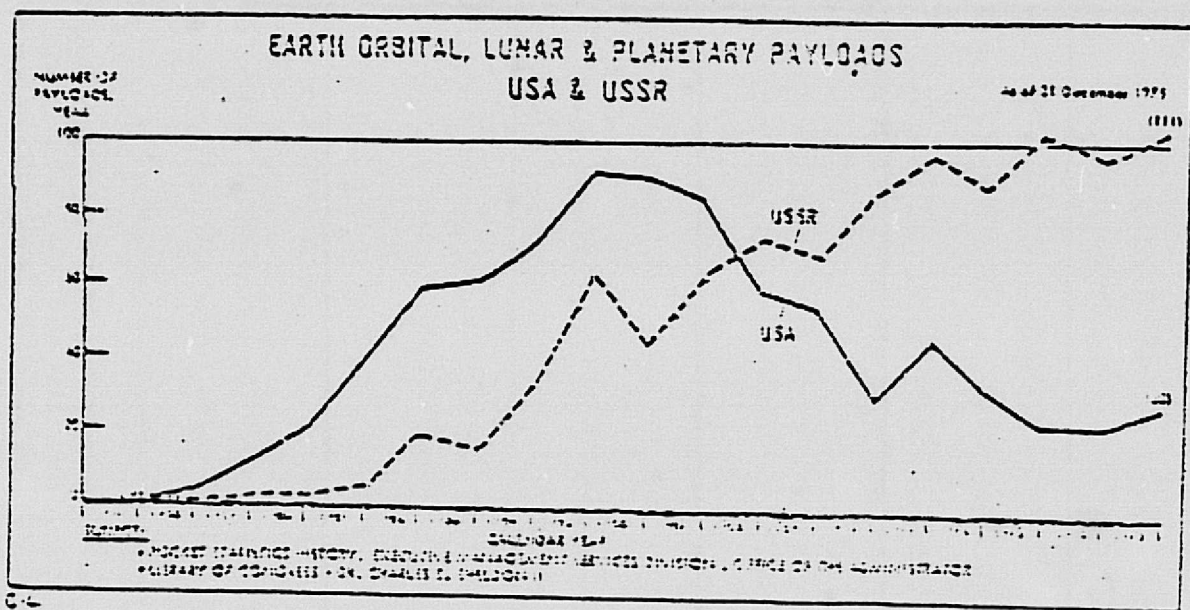
PAYLOADS

- O MOST DRAMATIC DOWNTREND IS IN SPACE
- O ALL U.S. MISSIONS - CIVIL, MILITARY, COMMERCIAL SHOWN
- O DASHED LINE SHOWS SOVIET COMMITMENT
 - WE BOTH LAUNCHED THE SAME NUMBER IN 1968
 - LAST YEAR THEY LAUNCHED 4 TIMES THE U.S. NUMBER
- O ON BALANCE U.S. MISSIONS - BETTER ENGINEERED
 - MORE PRODUCTIVE
- O BUT SOVIETS OUTSPEND U.S. 2:1
EMPLOY ~600,000 VS. U.S. 150,000 (INCLUDING DOD)
ROUTINELY INCREASE PROGRAM BECAUSE
RETURNS TO ECONOMY, MILITARY AND PRESTIGE
ARE SO GREAT
- O WE BELIEVE THEY ARE RIGHT
- O SOVIETS LEAD IN
 - SPACE WEAPONS
 - SAMPLE RETURN TECHNOLOGY

AND HAVE CAPABILITY

 - SPACE STATION
 - COMMUNICATION, WEATHER, NAVIGATION AND OBSERVATION
- O THEY HAVE NO SHUTTLE/BUT WE MUST USE IT TO MAINTAIN EDGE
- O SUMMARY - A DANGER OF EROSION BIT BY BIT LOSS UNTIL TOO LATE
- O WE BELIEVE TIME FOR NATIONAL R&D POLICY FOLLOWING UP'
YOUR ACTIONS OF '77 BUDGET
 - INCENTIVES TO INDUSTRY
 - PARTNERSHIP WITH GOVERNMENT
 - EDUCATE CITIZENS ON ROLE OF TECHNOLOGY
 - CARRY OUT LEADERSHIP PROGRAMS IN R&D
- O NASA HAS SOME SUGGESTIONS

Pa. From original.



SUMMARY OF SUCCESSFUL USA MISSIONS & USSR ANNOUNCED PAYLOADS

As of 31 Dec 75

	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Total
NASA (includes NASA 1957-1958)	0	0	2	4	15	23	23	22	22	22	22	22	22	22	22	22	22	22	22	22
NASA USA Gov't Agencies	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NASA USA Commercial	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NASA International	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL NASA	0	0	2	4	15	23	23	22	22	22	22	22	22	22	22	22	22	22	22	22
Air Force	0	0	1	1	12	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
Naval	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Army	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DOD	0	0	1	1	12	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
TOTAL USA	0	0	3	5	27	45	45	44	44	44	44	44	44	44	44	44	44	44	44	44
TOTAL USSR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NUMBER OF UNSUCCESSFUL PAYLOADS OR MISSED PAYLOADS (Not included in previous totals)																				
NASA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NASA USA Gov't Agencies	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NASA USA Commercial	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NASA International	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL NASA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DOD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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Source: NASA Historical Trends
Jan 1976

OPPORTUNITIES FOR MAJOR THRUSTS

OPPORTUNITIES FOR MAJOR THRUSTS:

- INDUSTRIALIZATION OF SPACE
- LEADERSHIP IN AERONAUTICS AND AVIATION
- DEVELOPMENT OF SPACE SYSTEMS FOR CIVIL NEEDS
- EXPLORATION OF THE UNIVERSE FOR NEW KNOWLEDGE

► THEIR PURSUIT WILL:

- REGAIN PREEMINENCE
- CREATE NEW INDUSTRIES
- STRENGTHEN U. S. ECONOMY
- REDRESS TECHNOLOGY BALANCE
- CAPITALIZE ON UNIQUE NASA CAPABILITIES

IMPORTANCE OF NASA TECHNOLOGY

IMPORTANCE OF NASA TECHNOLOGY

- ▣ **AERONAUTICS TECHNOLOGY HAS CREATED A \$30 BILLION INDUSTRY**
- ▣ **\$7 BILLION IN BENEFITS FROM NASA ADVANCES IN FOUR AEROSPACE TECHNOLOGIES ALONE**
 - **GAS TURBINES**
 - **INTEGRATED CIRCUITS**
 - **CRYOGENIC INSULATION**
 - **STRUCTURAL ANALYSIS**
- ▣ **THERE IS A 14 TO 1 PAYOFF OVER 10 YEARS FOR EVERY NASA DOLLAR SPENT**
- ▣ **EACH INDUSTRIAL JOB ON NASA WORK GENERATES 1.5 ADDITIONAL JOBS**

▶ **NASA IS A GOOD INVESTMENT**

REFERENCES

1. ORI Data Analysis (~~to be supplied~~)
2. G. Low Memo, NASA Productivity, 3/24/76, Based upon Mathematica & Chase Studies.

1974

U.S. Sales/Revenues

Aircraft Sales

\$ 14.0 billion

Airline Revenues

Domestic Trunk Lines 9.9 bil

International 2.9

Domestic Local 1.3

Supplemental .4

Air Cargo, domestic 2.8

Air Cargo, international 2.0

Total airline revenues 19.3

Total Aircraft Sales/Airline Revenues \$ 33.3 billion

NASA TECHNOLOGY PAYS HUGE DIVIDENDS

The economic impact of NASA's R&D expenditures and those of similar high-technology programs is to increase productivity both through direct applications of aerospace technology (e.g., communication satellites, improved aircraft, etc.) and indirectly (but significantly) through the development and dissemination of advanced technology which is then applied in many other sectors of the economy. Indirect applications may be in "new" products and services (e.g. miniaturized calculators, heart pacemakers, video tape storage and retrieval systems, etc.) or in lower production costs for existing products and services (e.g., integrated circuits for electronic equipment in products and processes, gas turbines, etc.).

Chart 4 summarizes the results of two major studies that have been undertaken to quantify and document the productivity impacts of NASA R&D expenditures. A study by Mathematica, Inc., the "Morgenstern Study," summarized in the upper half of the chart, estimated the contribution of NASA R&D to four major technological improvements -- gas turbines, integrated circuits, cryogenic insulation, and computerized structural analysis. The benefits resulting from NASA's work in these four technologies were estimated to be in the neighborhood of \$7 billion. Because the Mathematica study only considered a selected group of spinoffs, further analysis was undertaken by Chase Econometric Associates, Inc., to ascertain the total spinoff impact from NASA technology. The Chase study statistically quantified the contribution of NASA R&D expenditures to productivity growth rates of the national economy. Key results of this study are presented in the lower half of Chart 4. The highly beneficial impact of NASA R&D found in this study results from the large impact Chase estimates that NASA R&D has on productivity growth. As shown in the chart, there is, over a 10-year period, a gain of \$14 in additional productive capacity (real GNP) for each \$1 of additional NASA R&D spending. Equally important are the effects of productivity growth increases on employment and inflation. As productivity growth increases and the economy expands at a faster pace, demand for labor increases and more workers find jobs. Here Chase estimates that a sustained real increase of \$500 million (1958 dollars) in NASA R&D beginning in 1975 and continuing through 1984 will, by 1984, generate 400,000 more jobs.

NASA TECHNOLOGY PAYS HUGE DIVIDENDS

○ MORGENSTERN STUDY

- GAS TURBINES IN ELECTRIC POWER GENERATION
- INTEGRATED CIRCUITS IN CONSUMER PRODUCTS
- SPACE-DERIVED INSULATION FOR CRYOGENICS
- COMPUTERIZED STRUCTURAL ANALYSIS

\$7 BILLION
IN BENEFITS

○ CHASE ECONOMETRICS STUDY

- EACH DOLLAR INVESTED RETURNS \$14 TO THE ECONOMY OVER
A 10-YEAR PERIOD THROUGH PRODUCTIVITY

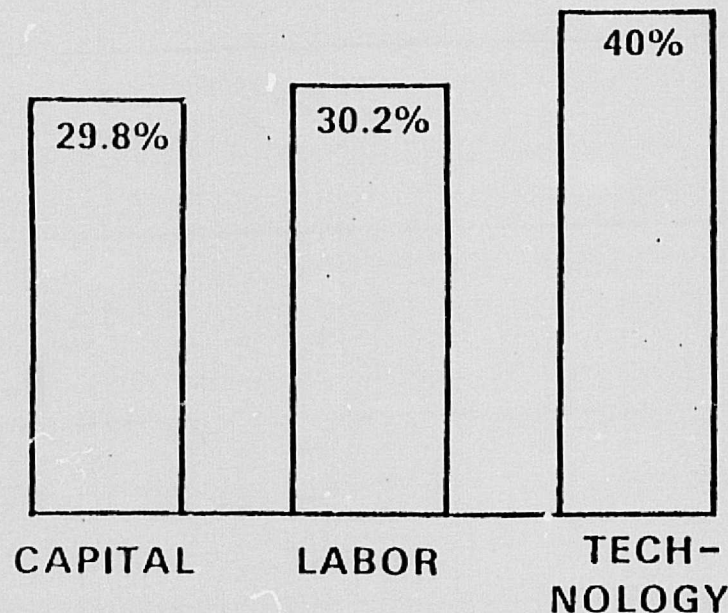
- A \$500M SUSTAINED INCREASE IN NASA R&D, COMMENCING IN 1975,

- LOWERS CONSUMER PRICE INDEX BY 1% BY 1984
- LOWERS UNEMPLOYMENT BY .2% BY 1984
- INCREASES 1984 EMPLOYMENT BY 400,000 WORKERS
- INCREASES REAL GNP BY \$11.3 BILLION
- YIELDS 38% RETURN ON INVESTMENT IN 10 YEARS
- AND FURTHERS NATIONAL OBJECTIVES IN SPACE AND AERONAUTICS

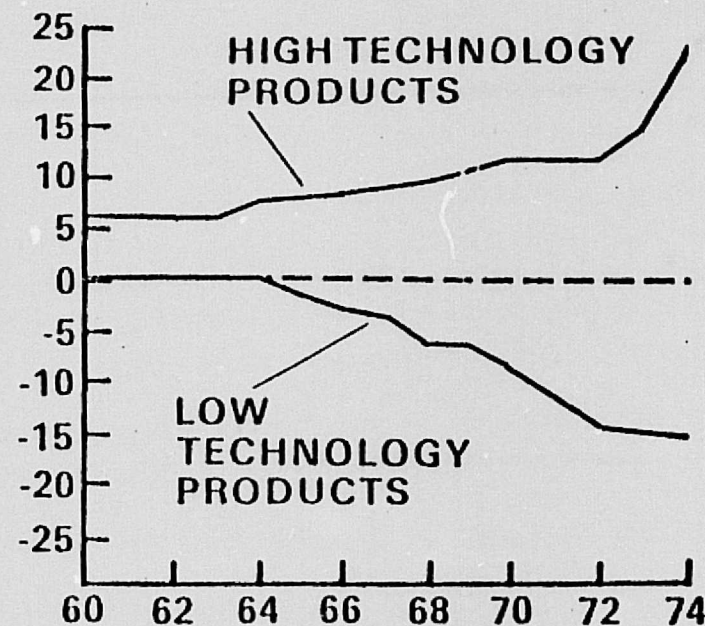
THE VALUE OF TECHNOLOGY

THE VALUE OF TECHNOLOGY

THE MAJOR SOURCE OF
PRODUCTIVITY GROWTH



\$ BILLIONS TRADE BALANCE



▶ PRODUCTIVITY AND EXPORTS MEAN:

■ U.S. JOBS

■ INDEPENDENCE

□ STANDARD OF LIVING

PRODUCTIVITY

- (3) • THUROW, DENISON AND KENDRICK STUDIES REMARKABLY CONSISTENT IN IDENTIFYING TECHNOLOGY AS MAJOR CONTRIBUTOR TO PRODUCTIVITY INCREASES.
- (4) • TECHNOLOGICAL ADVANCEMENTS IN INDUSTRIALIZED NATIONS ACCOUNT FOR 50 - 90% OF ALL PER CAPITA OUTPUT.
- (5) • U.S. PRODUCTIVITY GROWTH RATE AS WELL AS "RELATIVE" STANDARD OF LIVING IS DECLINING IN COMPARISON WITH JAPAN, NETHERLANDS, SWEDEN AND WEST GERMANY. TRENDS ARE EXPECTED TO CONTINUE.

HIGH TECHNOLOGY TRADE BALANCE

(6) •		JOB GROWTH	SALES GROWTH
		10.8%	16.5%
	HIGH TECHNOLOGY Co's.		
	MATURE COMPANY'S	1.9%	7.8%

- (7) • R&D INTENSIVE TRADE BALANCE INCREASED FOURFOLD OVER THE 1960-74 PERIOD AND DOUBLED BETWEEN 1970-74.

SPECIAL VALUE OF NASA TECHNOLOGY

- (8) • NASA EXPENDITURES ARE AN EFFECTIVE SHORT TERM MECHANISM FOR REDUCING UNEMPLOYMENT IN THAT THEY ARE LABOR INTENSIVE AND NON INFLATIONARY. EVERY \$100 MILLION OF NASA SPENDING IS EQUIVALENT TO 4000 DIRECT JOBS AND THROUGH MULTIPLIER EFFECTS, 6000 INDIRECT JOBS.
- (9) • CPI REDUCTIONS COME ABOUT DUE TO PRODUCTIVITY/WAGE INCREASES WITHOUT PRESSURE ON PRODUCTION COST OR PRODUCT PRICE.

VIEWGRAPH REFERENCES

1. Productivity & the Economy, Revised 1973 Edition, Bulletin 1779, U.S. Department of Labor, Bureau of Labor Statistics.
2. Science Indicators - 1974, National Science Board.

BACKUP SHEET REFERENCES

3. Productivity & Economy, Ibid.
- 4.&5. George Low Memo, 3/24/76, "NASA Productivity" based on SRI Study.
6. Business Week, 2/16/76, pgs. 57, 58.
7. Science Indicators, Ibid.
8. George Low Memo, Ibid, based on Chase Econometrics Study.
9. George Low Memo, Ibid, based on Mathematica Study.

The sources of growth

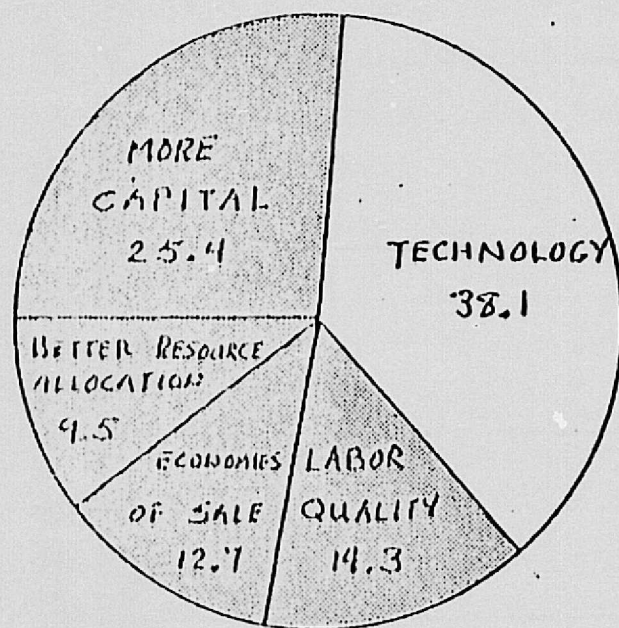
The factors affecting productivity growth are so interrelated that determining the separate effect of each one is difficult. Moreover, the economists who have attempted this task — Denison, Kendrick, Thurow, Griliches, Jorgensen, and Christiansen, among others — have come up with different measures because of differences in definitions, concepts, and assumptions.

It is not possible to compare the results of all the research undertaken to date in this area, since not all researchers have focused on the same factors. However, three studies — those by Edward Denison, John Kendrick, and Lester Thurow — encompass similar factors and thus provide a good idea of current thought in this area. Though their measures differ, they all conclude that improved technology and the availability of more capital per worker have been the major sources of productivity growth.

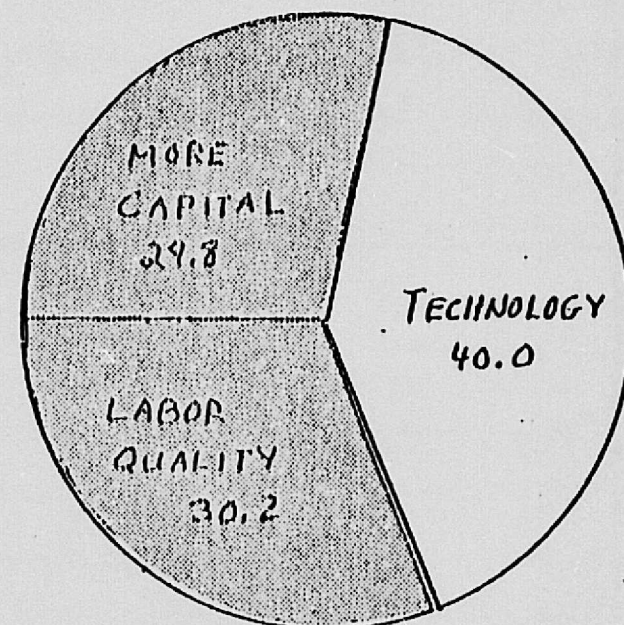
For all three researchers, technology refers not to the measured effect of technological improvements but to the residual — the part of productivity growth not accounted for by the other factors measured. One reason that Kendrick's residual exceeds Denison's is that it includes the effects of economies of scale and improved resource allocation, which Denison measured separately. Thurow's residual is smaller than Kendrick's mainly because he assigned technological progress embodied in labor or capital to the part of productivity growth that he attributed to those two factors.

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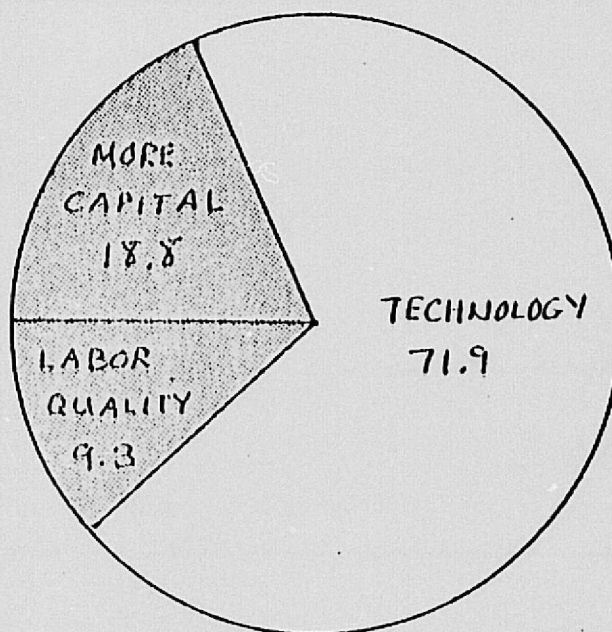
SOURCES OF PRODUCTIVITY INCREASES



DENISON



THUROW



KENDRICK

SOURCE: PRODUCTIVITY AND THE ECONOMY
 REVISED 1973 EDITION
 BULLETIN 1779
 U.S. DEPARTMENT OF LABOR
 BUREAU OF LABOR STATISTICS

and nearly five times less than increases in Japan, which recorded the largest gains. However, starting from a relatively high level of productivity in 1960, the United States might not be expected to sustain the same high proportional gains as countries starting from a lower productivity base.

The effectiveness of a nation's productivity level is perhaps best indicated by the measure of "unit labor cost" (i.e., hourly labor costs divided by output per man-hour). If gains in productivity exceed increases in the cost of labor, then unit labor costs drop, products can be produced at less cost, and sold at lower prices, placing a nation in a favorable competitive position in the international market.³⁹

Trends in this index for manufacturing industries are shown for the five countries in figure 1-18. It can be seen that productivity gains in the U.S. were sufficient to offset increases in labor cost from 1960 through 1965 and again from 1970 through 1973. Productivity rises in 1974 were negligible, however, while hourly labor costs had the largest yearly gain of the entire period. As a result, unit labor costs in manufacturing industries rose more rapidly than in any other year since World War II.

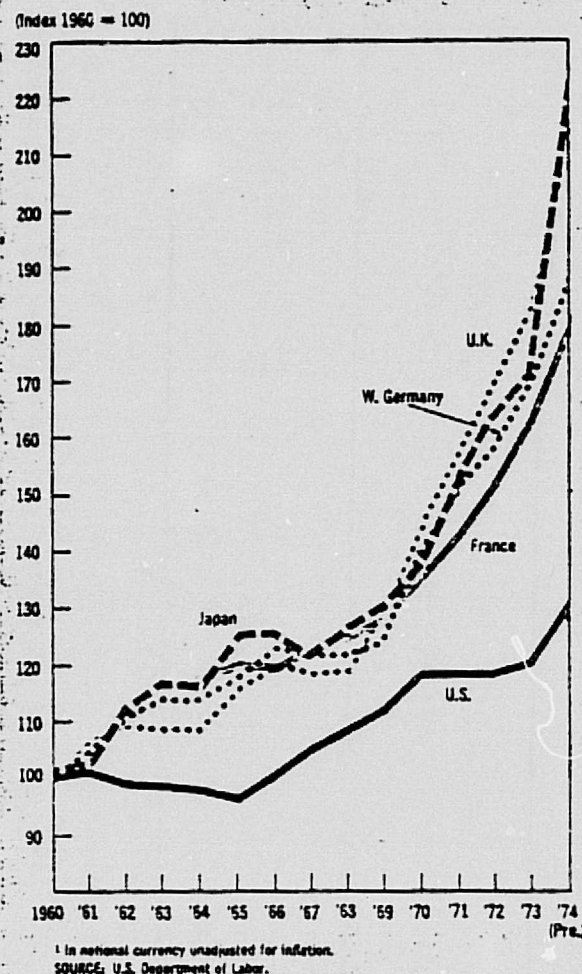
Gains in hourly compensation in 1974 exceeded advances in productivity in other countries also, and by even wider margins than in the United States. Thus, unit labor costs increased to an even greater extent in foreign manufacturing. The 1973-74 increase in Japan was nearly 30 percent and in the United Kingdom nearly 20 percent, both of which were the largest year-to-year gains in unit labor costs experienced by these countries during the 1960-74 period.

Balance of trade in R&D-intensive products

The U.S. position in world trade depends upon a variety of factors, including the price of its products, the effectiveness of its international marketing, trading arrangements with other countries, and its performance in technological innovation. Such innovation, as discussed elsewhere in this report, depends significantly upon research and development.

³⁹ For a discussion of recent trends in these factors, see Patricia Capdevielle and Arthur Neef, "Productivity and Unit Labor Costs in the United States and Abroad", *Monthly Labor Review*, July 1975; for a detailed analysis of the role of these factors in international trade, see *Competitiveness of U.S. Industries*, United States Tariff Commission, 1972.

Figure 1-18
Unit labor cost¹ in Manufacturing Industries,
by Selected Countries, 1960-74



The precise role of R&D and technological innovation in U.S. trade have not been determined, although recent studies suggest that it is substantial.⁴⁰ Some indication of this is provided by analyzing the U.S. trade balance in terms of the products involved, with the latter classified according to the relative level of R&D investment of the industries which produce the products. For this purpose, products from industries⁴¹ with (a) 25 or more scientists and

⁴⁰ Raymond Vernon (ed.), *The Technology Factor in International Trade*, (New York: Columbia University Press, 1970).

⁴¹ Only manufacturing industries (which account for nearly all industrial expenditures for R&D) are included in the analysis.

engineers engaged in R&D per 1,000 employees and (b) company-funded R&D amounting to at least 3 percent of their net sales, were regarded as "R&D-intensive" products.⁴² Based on these criteria, the product areas identified as R&D-intensive are (1) chemicals, (2) nonelectrical machinery, (3) electrical machinery, (4) aircraft and parts, and (5) professional and scientific instruments. All other manufactured products were regarded as non-R&D-intensive.

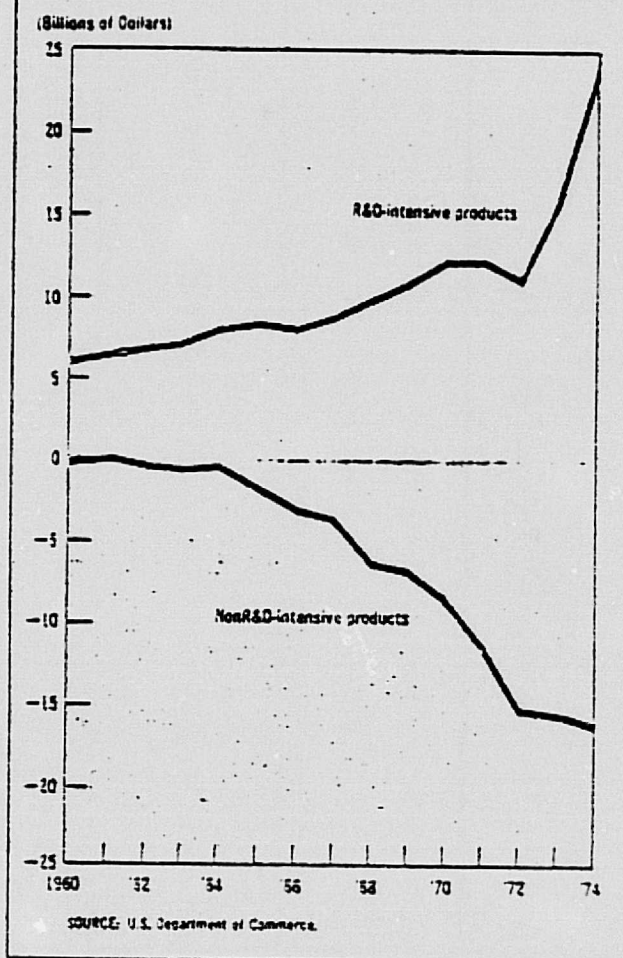
The U.S. trade balance (exports minus imports) associated with these two categories of products is shown in figure 1-19.⁴³ The favorable balance in R&D-intensive products is clearly indicated: the balance increased fourfold over the 1960-74 period and doubled between 1970-74 alone. In contrast, the United States had large and increasing trade deficit in non-R&D-intensive products. The principal products in this area which accounted for the deficit were motor vehicles, textiles, and metals.⁴⁴

The favorable U.S. trade balance in products from R&D-intensive industries is shown in figure 1-20.

Nonelectrical machinery accounted for nearly one-half of the favorable balance in R&D-intensive products. The recent growth in the balance for this area was largely the result of increased export of electronic computers, construction equipment, and mining and well-drilling machinery.

Aircraft and parts contributed approximately one-fifth of the positive balance in R&D-intensive products in 1974. This is the only

Figure 1-19
U.S. Trade Balance in R&D-intensive and NonR&D-intensive Manufactured Products, 1960-74



⁴² This grouping, of course, is an approximate one. Products and industries, although highly correlated at the gross level, do not perfectly coincide, with the result that not all products manufactured by a high R&D-performing industry can be considered R&D-intensive.

⁴³ The export statistics presented here include all merchandise shipped from the U.S. customs area, with the exception of supplies destined for U.S. Armed Forces abroad for their own use; shipments for relief purposes or under military assistance programs are included. The import statistics cover foreign merchandise received in the U.S. customs area.

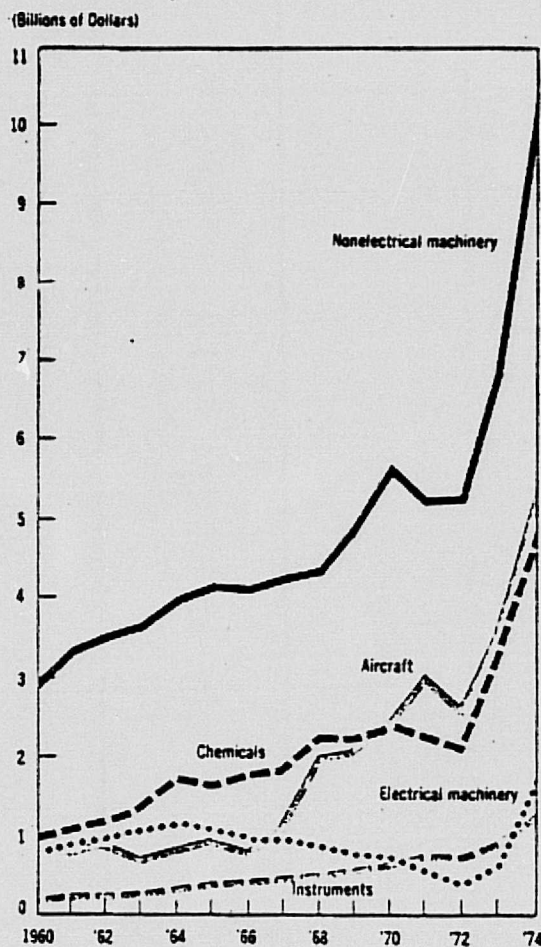
⁴⁴ The trends in U.S. foreign trade presented here were influenced by recent adjustments in the international monetary system. In December 1971, the United States reduced the par value of the dollar; in March 1974, all of the major world currencies converted to a system of floating exchange rates. The precise impact of these changes on the U.S. trade position is not known, but in general they are thought to enhance the competitiveness of U.S. exports. A detailed discussion of this topic is presented in the *Economic Report of the President*, Council of Economic Advisers, 1975.

one of the five areas in which imports decreased between 1973 and 1974.

Chemicals accounted for an additional one-fifth of the positive balance in R&D-intensive products. The recent increase in net exports of chemicals was due largely to growth in the exports of plastics, medicinal and pharmaceutical products, and manufactured fertilizers.

Electrical machinery had the smallest margin of exports over imports, as a result of large and increasing imports in telecommunications apparatus, without comparable increases in exports of other types of electrical machinery.

Figure 1-20
U.S. Trade Balance in R&D-intensive
Manufactured Products, by Product
Group, 1960-74



SOURCE: U.S. Department of Commerce.

Professional and scientific instruments maintained a steady but small growth in net exports through 1974.

There have been substantial changes over the last decade in the mix of products underlying the favorable trade balance. Several products have become increasingly important to the maintenance of the positive trade balance in R&D-intensive products (including electronic computers, fertilizers, electronic tubes, tran-

sistors and semiconductor devices), while the contribution of other commodities (such as telecommunications apparatus) has led to a negative balance. This mixture of growing and declining exports illustrates the complexities of the present U.S. trade position. The underlying dynamics of the position, however, are partially explained by the "product cycle" concept.⁴⁵ Trade in manufactured goods, according to this concept, typically follows a cycle in which the United States initially establishes a net export position with the introduction of a new product, maintains this position until the technologies and skills necessary for manufacturing the product are developed elsewhere, and then becomes an importer as the production is standardized and moves abroad to minimize costs. This concept implies that the product structure of U.S. exports must have a continuous infusion of new products in order for the United States to maintain a favorable trade position.

The favorable position of the United States in R&D-intensive products is based primarily on exports to developing nations, countries of Western Europe, and Canada.⁴⁶ The U.S. trade balance in these products is shown in figure 1-21 for selected areas and countries. In 1973, the developing nations accounted for 44 percent of the positive U.S. trade balance; nonelectrical machinery and chemicals were particularly large net export commodities for the United States in trade with these nations. In the case of trade with Western Europe, the United States had its largest net exports in the areas of aircraft and nonelectrical machinery (particularly in computers). U.S. net exports to Canada are concentrated in the areas of nonelectrical and electrical machinery.

A trade deficit in R&D-intensive products developed with Japan in the mid-1960's and persisted through 1974. This deficit occurred primarily in electrical machinery products (particularly consumer electronics) and to a lesser degree in professional and scientific instruments and nonelectrical machinery. Only in the areas of chemicals and aircraft does the

⁴⁵ Raymond Vernon, "International Investment and International Trade in the Product Cycle", *Quarterly Journal of Economics*, Vol. 80, May 1966.

⁴⁶ For a more complete discussion of these relationships see Keith Pavitt, "International Technology and the U.S. Economy: Is there a Problem?" in *The Effects of International Technology Transfers on U.S. Economy*, National Science Foundation, Papers and Proceedings of a Colloquium (NSF 74-21).

- Attachment 2 -

- 5 -

PRODUCTIVITY -- THE KEY TO A HEALTHY ECONOMY

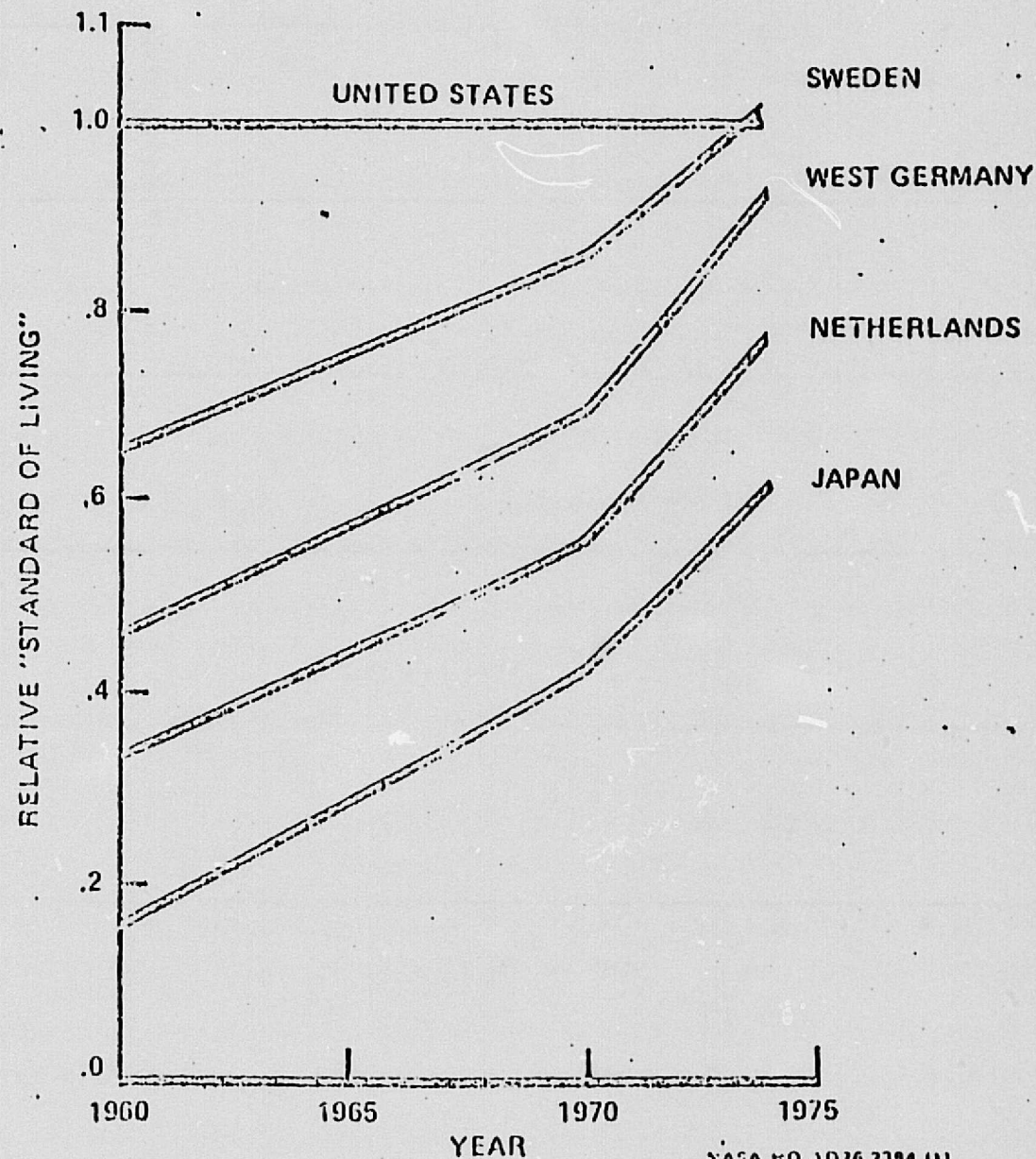
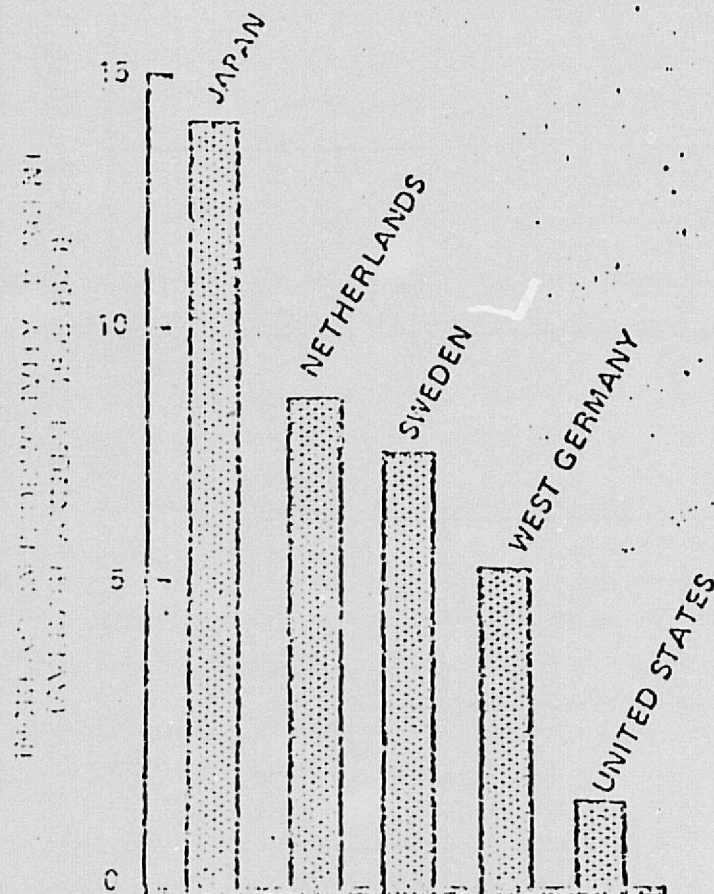
The dramatic post-World War II increases in the standard of living in developed countries of the world is in large part accounted for by growth in technological progress which has enhanced the productive capacities of primary inputs -- land, labor, and capital. Although sketchy, the evidence arrived at by those working in the area of economic growth suggests that technological advancements in the industrialized nations of the world account for between 50 and 90 percent of all growth in per capita output. Chart 2 shows productivity growth rates and relative standards of living for the United States and four other nations with well-developed economies -- West Germany, Sweden, The Netherlands, and Japan.

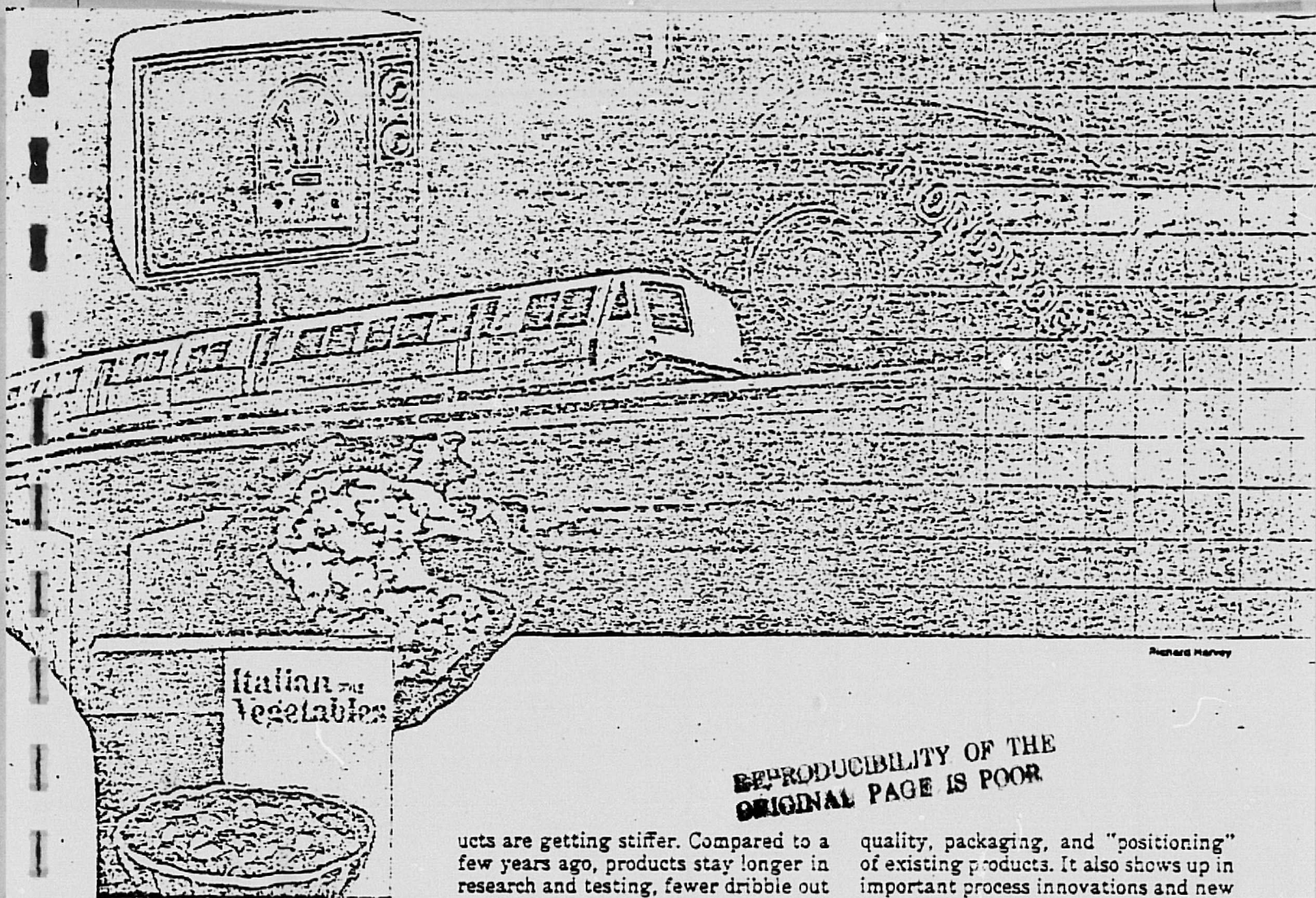
In the left-hand panel of this chart, five year average annual growth rates for the 1965-1970 period are given for each of these countries. The striking feature of these data is the significant shortfall of U.S. productivity growth rates relative to those of the other four countries, 2 percent vs. 5 to 14 percent. The consequence of the wide differences in productivity growth rate is seen in the right-hand panel. Here the "standard of living" (as measured by per capita gross domestic product) is shown for the same four other nations relative to that of the U.S. for the period 1960 to 1974. In 1960, the relative standard of living in the United States was well above all four of these other countries. By the mid-70's, all four countries had gained markedly on the U.S., with Sweden closing the entire gap and surpassing the U.S. by 1974. Moreover, these trends are expected to continue. Long-range predictions made by the Stanford Research Institute's Long Range Planning Service show the U.S. falling over the next 15 years to a position of fifth in terms of per capita GNP behind Sweden, Switzerland, West Germany, and France.

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PRODUCTIVITY -- THE KEY TO A HEALTHY ECONOMY





Richard Harvey

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Robert A. Krueger, research director for B. F. Goodrich Chemical Co., adds: "Even when there is a definite need in the marketplace for a new material, say a new specialty chemical, and there exists the technology to produce the material, the economics for going ahead with the venture may not justify it in management's eyes. This is particularly true where a new production facility is needed."

The impact of such thinking varies from company to company. Among high-technology fields that are rooted in innovation—instrumentation, computers, and electronics (page 60), for instance—important products and processes continue to churn out of the research lab. In many other industries, from steel and chemicals to paper, packaged goods, and autos (page 53), product innovation has leveled off or dropped. Yet nearly all leading companies, whether strong innovators or not, share one response: Their broader corporate approach to innovation is becoming more defensive. Among the key shifts in direction:

- Performance demands on new prod-

ucts are getting stiffer. Compared to a few years ago, products stay longer in research and testing, fewer dribble out to the market, and those that do reach the market must often pay back their investment much earlier than before, sometimes in only one-third to one-half the time. This is because today's market pressures have cut many product life cycles by 40% to 60% from what they were 10 years ago. As John Golden, a director of group market development for Systron-Donner Corp., notes: "We're trying to have our failures earlier."

- Top management is getting deeper into key decisions on innovation and new-product investment. That does not mean a "squelching of new products," stresses Roger R. Robbins, executive vice-president of Purex Corp. "In the last year, on the basis of high capital risk, I turned down new products at a rate at least twice what I did a year ago. But in every case, I tell my people to go back and bring me some more new-product ideas."

- Some of the innovative thinking that previously went into new products is being redirected back into existing products and processes. While that contributes to any lag in technological innovation, it stimulates more marketing innovation. This shows up in better

quality, packaging, and "positioning" of existing products. It also shows up in important process innovations and new manufacturing efficiencies that help increase productivity of existing systems and hold over-all costs and prices down.

The Impact of a slowdown

For an economy built on innovation, the implications of a technological slowdown or redirection are stupendous. "The concern that one could have is that we will not be working on the major needs of the future, because they require more extensive effort," says Philip D. Aines, vice-president of research and engineering at Pillsbury Co. "It's much more difficult to come up with a synthetic meat product than a lemon-lime cake mix. But you work on a lemon-lime cake mix, because you know exactly what that return's going to be. A synthetic steak is going to take a lot longer, require a much bigger investment, and the risk of failure will be greater."

Richard S. Morse, senior lecturer at the Massachusetts Institute of Technology, takes that thinking one step further. He warns of the impact on the country's total economic growth. In a recent report he coauthored for the Commerce Dept., Morse cites the per-

formance record of five leading high-technology innovators that have refused to knuckle under to new-product pressures: IBM, Xerox, Texas Instruments, 3M, and Polaroid. From 1945 through 1974, their annual compounded growth rate works out to 16.5% in sales and 10.8% in jobs. The record is far less impressive for six typically "mature," or less innovative, companies: Bethlehem Steel, Du Pont, GE, General Foods, International Paper, and Procter & Gamble. Their growth rate averaged 7.8% in sales and 1.9% in jobs.

Morse goes on to warn that new high-technology growth companies are no longer being formed "in sufficient numbers to provide the jobs and technical products for export which will be needed in the decades ahead." That would mean less economic growth, fewer jobs, a loss of foreign markets, greater import competition in domestic markets, and finally, of course, a potentially devastating rise in trade deficits.

"Just look at it in terms of a single major postwar innovation, the office copier, and what our economic life would be without it," says market researcher Solomon Dutka, president of Audits & Surveys Co. The first Xerox copier, he notes, led to a \$4.5 billion industry that employs more than 150,000 persons. "Knock a couple of very innovative industries like this out of our economy," Dutka warns, "and you begin to see how much impact a slower rate of innovation might have."

Such a prospect is a far cry from that of only a few years ago. All through

the 1940s, 1950s, and 1960s, the research environment encouraged innovation among big and small companies alike. Money was plentiful, risk-taking was feasible, and the goals of the \$36 billion research establishment were clear and distinct because they coincided with two prime national objectives: defense and, later, space.

Then everything began coming apart. Both the space program and war effort started winding down. This cut into basic-research spending, blurred national research goals, and inevitably led to what Jacob E. Goldman, group vice-president of Xerox Corp., calls an "over-preoccupation with the doctrine of relevance." In other words: too much emphasis on applied research aimed at the marketplace and too little on basic research that explores why things happen. By its nature, applied research tends toward variations on existing technologies, while basic research is more likely to produce radical, new concepts and true, quantum-leap innovations.

About the same time, the public's attitude toward industry and its products also began changing. Consumers became more conservative in their buying and more suspicious about what they were buying. As pollster Lou Harris put it recently: "After three decades of hearing about the miracles of American knowhow, the public feels cheated. Consumerism represents shaken confidence in American technology."

Above all, the whole regulatory climate started closing in. Some product

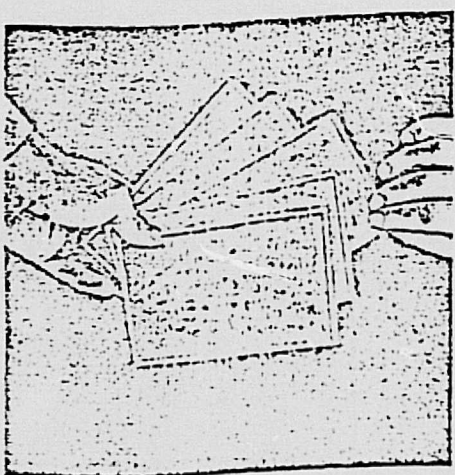
clearances began stretching out to six or eight years or longer. William F. Ballhaus, president of Beckman Instruments Inc., notes the impact on clinical instruments alone. "Growing regulation," he says, "has imposed upon us two choices: Either postpone market entry until we can complete every test required, or run the tests concurrently and increase the cost of getting the product on the market by 10% to 25%. Competition doesn't permit the former, so we pay more to develop and market our product."

The best odds

With pressures building, most innovation is now taking the path of least resistance, using as guideposts some rough laws of probability set down by A. T. Kearney Inc., management consultants. If a company brings out the ultimate in innovation, a new product in a new market, Kearney rates its chances at only 1 in 20. This might be the first blender for home use, say. Next on the Kearney scale is an old product moving into a new market—the home blender offered in the hospital field, for instance. Its chances are 1 in 4. A new product entering an old market has 1 chance in 2. This could be a home blender five times as fast as anything else on the market. Finally, there is the old or "me-too" product introduced in an old market. It has slightly less than 1 chance in 1.

Most companies now go where the odds are best: a new or old product in

Why Detroit resists change



"If there is any industrial area in the U.S. where an important new idea is absolutely necessary for survival, it is in the automobile industry. The oil

prospects for the world are so very dim that this largest of all American industries must have an important, original, inspired breakthrough sometime within the next 25 years, for by then we shall have to kiss goodbye to any means of locomotion which requires for its use the internal combustion of fossil fuels. What we must have is something so new, so radical, and so unanticipated that it would be folly to compartmentalize our thinking into how to go about pursuing this."

Those remarks were delivered in 1956 to a meeting of the American Physical Society by Jacob E. Goldman, then director of Ford Motor Co.'s scientific laboratory and now group vice-president for Xerox Corp. In the 20 years since then, the urgency for some important automotive breakthrough has intensified. Along with the height-

ened uncertainty of petroleum supplies, the U.S. automobile is now up against growing pressures from regulators, environmentalists, consumerists, and, of course, stiff import competition that has gobbled up nearly 20% of the domestic market.

Yet the \$93 billion auto industry is no closer to a breakthrough than it was in 1956. Experts may argue about when the golden age of automotive innovation ended, but few deny that it is dead. One Big Three engineer sums it up this way: "We've been playing with the same deck of cards for at least 25 years. What we call a new car is just a reshuffle."

Prisoner. Typically, auto executives have been concerned mainly with selling style, comfort, and status. As recently as two years ago, when asked about the importance of front-wheel drive as a technological innovation, Ford's President Lee A. Iacocca noted that the public "can't see it." Then he

NASA SPENDING IMMEDIATELY CREATES PRODUCTIVE JOBS

There are several aspects of NASA expenditures that make them a relatively effective short term mechanism in reducing unemployment, and accomplishing this reduction in a non-inflationary way. These are summarized in Chart 1:

- o NASA expenditures are labor intensive. About 85 percent of NASA spending goes directly to productive jobs and 15 percent goes for materials.
- o NASA expenditures are non-inflationary. There is significant unemployment, underemployment, and unused capacity in the aerospace industry, and increased NASA expenditures would not lead to labor shortages, or capacity bottlenecks with their attendant price increases. Furthermore, there would be no lag in putting people and machines to work.
- o Every \$100 million of NASA spending is equivalent of about 4,000 direct jobs per year.
- o The short-term demand multiplier effect of additional jobs created indirectly in the community and the economy at large is significant and brings the total number of jobs resulting from each \$100 million of NASA expenditure to as many as 10,000 jobs.

At 10,000 employees per \$100 million of expenditures, NASA is near the top of the list of Federal expenditures in terms of short-run employment generation. These figures are based on contractor data and econometric estimates of the employment impact of the aerospace industry on the California economy. Moreover, these figures are corroborated by preliminary results of the Chase Econometric Associates' study, The Economic Impact of NASA R&D (forthcoming), which considers the short-term impact of NASA expenditures within the context of the Chase Econometric model of the U.S. economy, as well as the long-term productivity effects quoted above.

The same sustained increase in NASA R&D also reduces the rate of consumer price increases. This is the case because, for every 1 percent increase in productivity growth, wages can be advanced by 1 percent without placing any upward pressures on production costs and product prices.

NASA OAST ADMINISTRATIVE CONTROL PROCEDURES

PRESENT CONTROL PROCEDURES

PROPOSED MEMORANDUM FROM
G. KAYTEN TO RX STAFF

Prepared by:

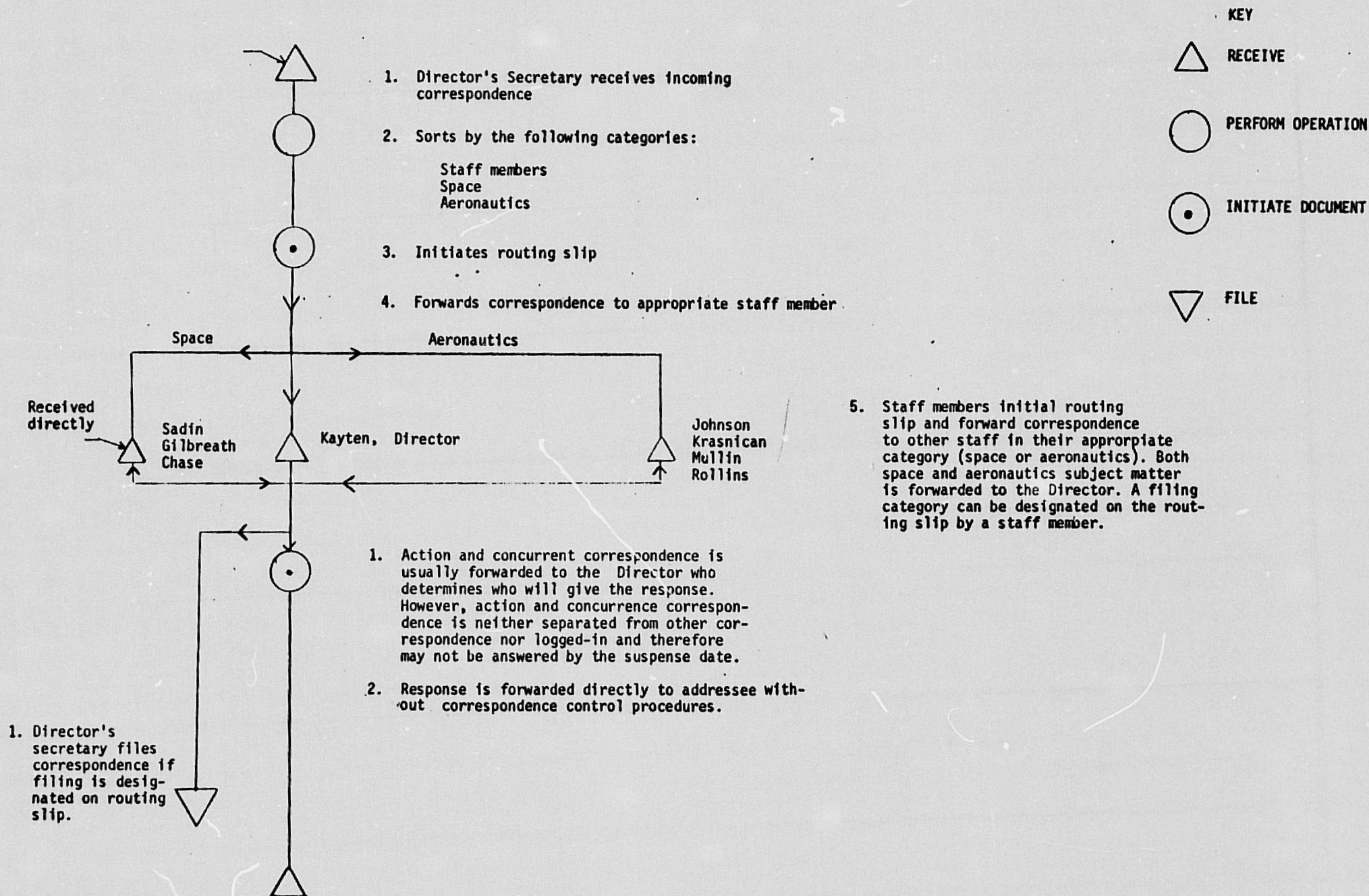
Operations Research, Inc.
July 15, 1976

PRESENT ADMINISTRATIVE CONTROL PROCEDURES

The current flow of correspondence is illustrated in Figure 1. Problems associated with this present flow stem from the fact that there are essentially no administrative or correspondence control procedures. Under the present procedures, action correspondence received by the Director's Secretary is not separated from the routine mail, nor logged in, nor issued a control slip, and therefore may not be answered by the suspense date. Filing categories are designated arbitrarily by various staff members on correspondence routing slips. This practice makes it difficult, if not impossible, to find correspondence when needed. Furthermore, responses to action correspondence are made directly to the addressee without any control or filing procedures. Thus, the lack of administrative control procedures in the Study, Analysis and Planning Office has been detrimental to its efficient operation.

An administrative control procedure, developed specifically for the Study, Analysis and Planning Office, is described in detail in the attached memorandum.

FIGURE 1
CORRESPONDENCE FLOW CHART PRESENT PROCEDURE



MEMORANDUM

TO: Study, Analysis and Planning Office Staff
FROM: G. G. Kayten
DATE: 15 July 1976
SUBJECT: Administrative Control Procedures

PURPOSE: To establish procedures for routing, responding to, controlling and filing correspondence and associated material pertaining to the Study, Analysis and Planning Office. The same procedures will be used for routing technical documents, however, procedures for filing and retrieving technical documents will differ from those used for correspondence and will be described in a forthcoming memorandum.

RESPONSIBILITY: The Secretary to the Director shall be responsible for receiving, routing and controlling incoming correspondence and for maintenance of the correspondence files.

PROCEDURES: The correspondence control procedure is illustrated in Attachment A-1.

Study, Analysis and Planning Director's Secretary:

- Incoming correspondence will be entered into the log sheet provided in Attachment A-2.
- A Correspondence Control Slip, Form 416A, shall be initiated for each piece of correspondence for which a Control Slip is appropriate or required. As a general rule, a Control Slip should be initiated for any correspondence that requires a response. In addition, the following types of correspondence shall be controlled:
 - Correspondence accompanied by technical literature or documents to be filed in the technical libraries.
 - Unsolicited proposals
 - Correspondence pertaining to conferences, seminars, technical committees, etc. inviting or requesting participation by Study, Analysis and Planning personnel.

Professional Staff:

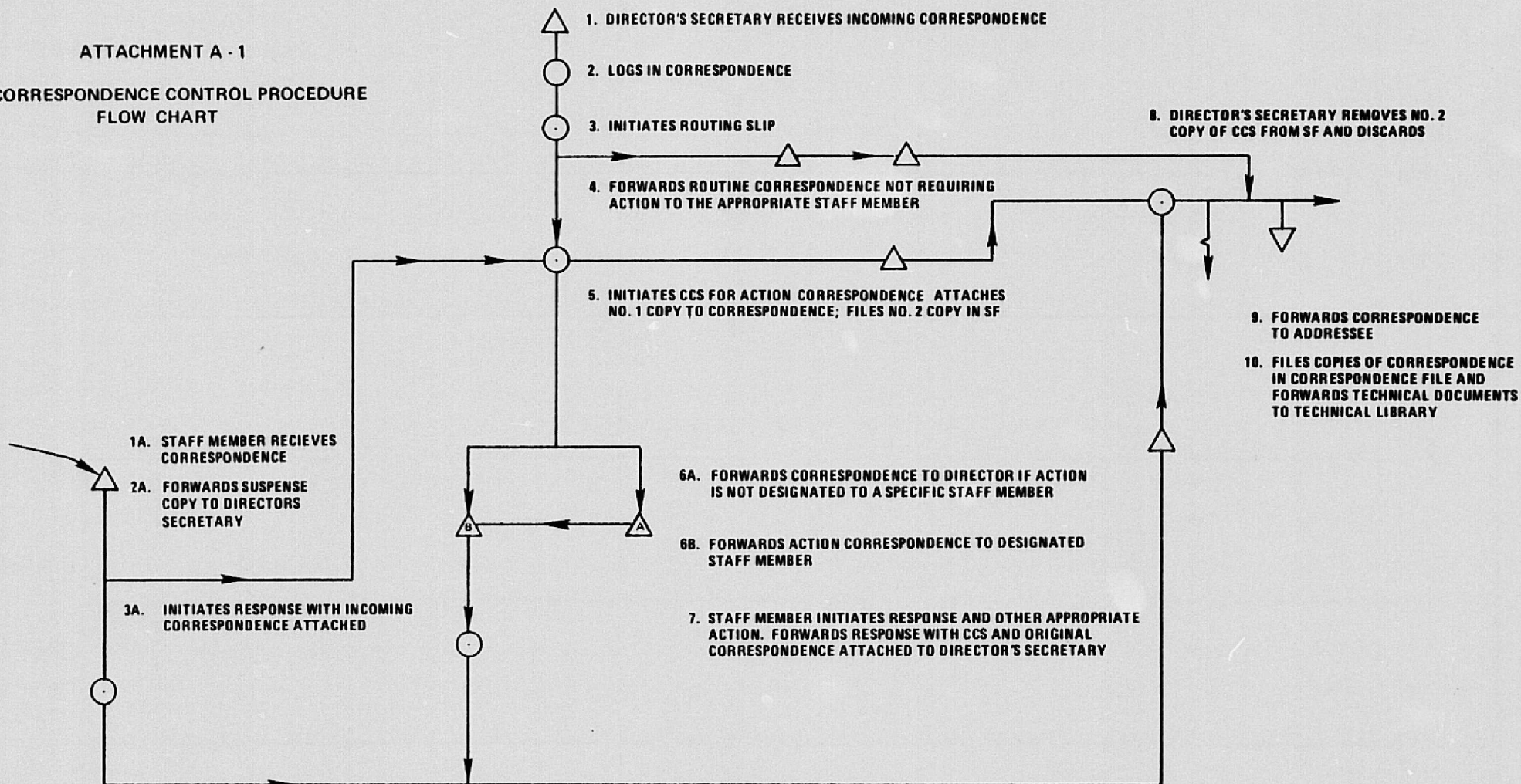
- A copy of correspondence pertaining to Study, Analysis and Planning received directly by staff (not through the Study, Analysis and Planning Office) and requiring a response should be forwarded to the Director's Secretary for initiation of control procedures.
- Incoming correspondence received by the Study, Analysis, and Planning Office and requiring control (see above) will be forwarded to the Professional Staff with a Correspondence Control Slip, Form 416A, attached. Responses to all such correspondence should be forwarded with the same correspondence control slip attached, to the Director's Secretary.
- A file of all Study, Analysis and Planning related correspondence, whether or not controlled by a Correspondence Control Slip, shall be forwarded to the Director's Secretary.
- Two file copies of all outgoing correspondence, plus a copy of trip reports, records of important telephone conversations and any other significant communications shall be forwarded to the Director's Secretary.
- When correspondence or other material is removed from the file and is to be taken from the immediate vicinity, a "Charge Out Record Card" (Optional Form 23) shall be inserted in place of the material removed. The title or a description of the material, the name of the person possessing the material, and the date removed from the file shall be entered on the charge out record card.
- All filing will be done under the direction of the secretary. Material to be filed or refiled should be placed in the "File" box located adjacent to the files.

Filing:

Subject, Chronological, Document Request and Suspense Files shall be developed and maintained. Attachment B-1 provides a potential subject classification code, and Attachment B-2 describes the Suspense File in detail.

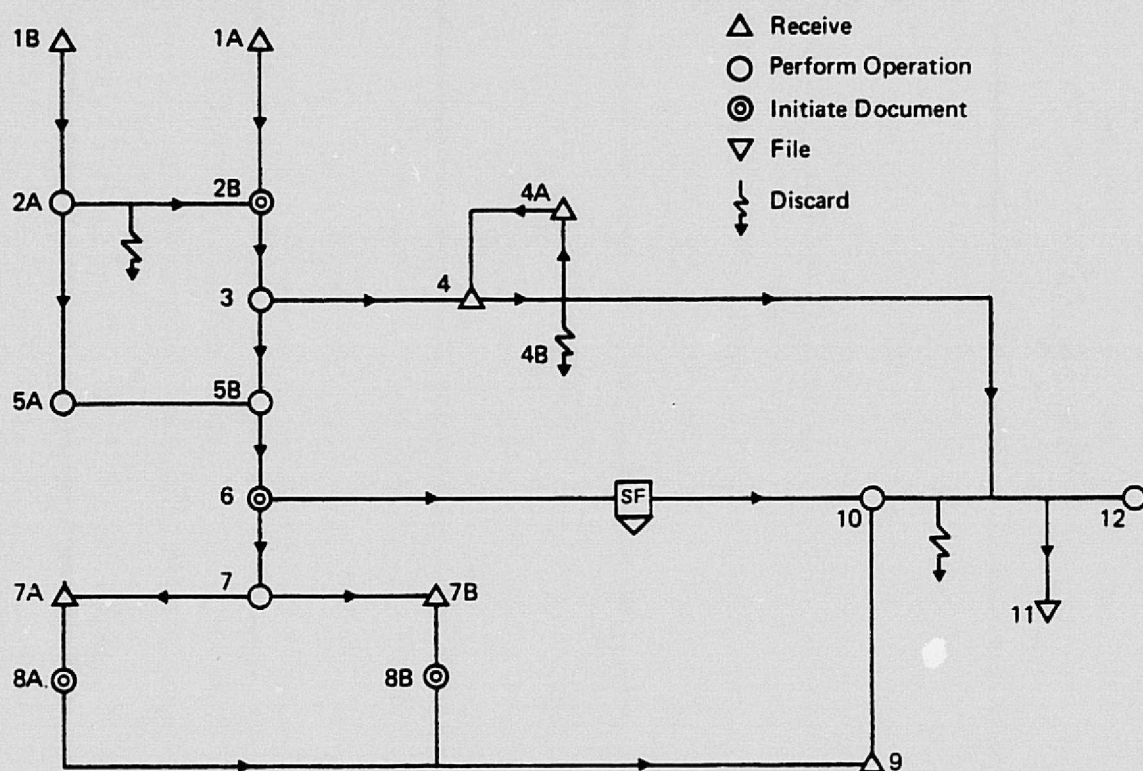
- Two copies of outgoing correspondence will be filed. The first file copy will be filed by subject and the second chronologically by date of origination.
- Incoming correspondence material other than technical documents will be filed in the correspondence file by subject. Technical documents will be filed in their appropriate library (Space or Aeronautics).
- Copies of correspondence control slips will be stored in a Suspense File. The Suspense File serves as a reminder that certain specific actions must be taken on a certain date.

ATTACHMENT A - 1
CORRESPONDENCE CONTROL PROCEDURE
FLOW CHART



KEY

- △ RECEIVE
- PERFORM OPERATION
- ⊙ INITIATE DOCUMENT
- ▽ FILE
- ⚡ DISCARD
- CCS CORRESPONDENCE CONTROL SLIP
- SF SUSPENSE FILE



1. A. Director's secretary receives incoming correspondence.
B. Staff member receives incoming correspondence.
2. A. Forwards routine correspondence to secretary or discards.
B. Initiates routing slip.
3. Forwards routine correspondence not requiring action to appropriate staff members.
4. Staff member receives correspondence; forwards to another staff member (4A), or discards (4B) or forwards to secretary for filing.
5. A. Forwards action correspondence to secretary for logging and routing.
B. Secretary logs in action correspondence.
6. Initiates CCS for action correspondence;
Attaches No. 1 copy to correspondence;
Files No. 2 copy in Suspense File (SF).
7. A. Forwards correspondence to Director if action is not designated to a specific staff member.
B. Forwards action correspondence to designated staff member.
8. A. Director initiates response. Forwards to secretary original correspondence with CCS attached.
B. Staff member initiates response. Forwards response with CCS and Original correspondence attached to secretary.
9. Secretary receives all action responses.
10. Secretary removes No. 2 copy of CCS from SF and discards.
11. Files copies of correspondence in correspondence file and forwards technical documents to technical library.
12. Forwards correspondence to addressee.

STUDY, ANALYSIS AND PLANNING OFFICE

INCOMING CORRESPONDENCE

CONTROL NO.	DATE RECD	ADDRESSED TO	FROM	SUBJECT	ACTION TO	DUE DATE	ACTION TAKEN

ATTACHMENT B-1

SUBJECT CLASSIFICATION CODE TABLE

1. GENERAL MANAGEMENT AND ADMINISTRATION
 - 1.1 Study, Analysis and Planning Office Memos
 - 1.2 OAST Memoranda
 - 1.3 Management Retreats
 - 1.4 Staff Meeting Notes
2. ORGANIZATION, AUTHORITIES, FUNCTIONS AND INTERNAL RELATIONSHIPS
 - 2.1 Organization Charts
 - 2.2 Functional Statements
 - 2.3 Staffing
 - 2.4 Position Descriptions
 - 2.5 Designation of Authority Announcements
 - 2.6 Physical Office Organization
 - 2.7 Telephone List Update
 - 2.8 Committees
 - 2.8.1 (Committees will be supplied by OAST Staff)
 - 2.8.2
 - 2.8.3
 - 2.8.4
 - 2.9 Meetings and Conferences
 - 2.9.1 (Arranged chronologically by OAST staff)
 - 2.9.2
3. EXTERNAL RELTIONSHPIS
 - 3.1 Public Relations
 - 3.2 Newspaper and Periodical Articles Pertaining to OAST
 - 3.3 Requests for Publications and Information
 - 3.4 Congressional Relations
 - 3.4.1 Correspondence
 - 3.4.2 Testimony Pertaining to OAST

- 3.4.3 Hearings
- 3.4.4 Meetings and Conferences - With Congressman or staff)
- 3.4.5 Laws

3.5 Government Relations

- 3.5.1 Presidential Documents - White House Correspondence
- 3.5.2 NASA Centers
- 3.5.3 Other Agencies

4. TRAVEL AND TRANSPORTATION

- 4.1 OAST and NASA Travel Directives and Memoranda
- 4.2 Travel Arrangements
- 4.3 Trip Reports
 - 4.3.1 Kayten
 - 4.3.2 Staff

5. ADMINISTRATIVE SUPPORT

- 5.1 Publishing and Graphic Services
- 5.2 Data Distribution Lists

6. EMPLOYMENT

- 6.1 Recruitment, Selection and Placements (Applications)
 - 6.1.1 Letters of Reference (NASA)
 - 6.1.2 Letters of Reference (External)
 - 6.1.3 Promotion and Internal Placement

7. EMPLOYEE PERFORMANCE AND UTILIZATION

- 7.1 Performance Evaluation
- 7.2 Incentive Awards and Employee Recognition

8. PROCUREMENT

- 8.1 Authorities/Responsibilities/Regulations
 - 8.1.1 Proposal Evaluation
- 8.2 Contracting
 - 8.2.1 Contracts - Active (Includes Progress Reports)

- 8.2.2 Contracts - Completed
- 8.2.3 RFPs
- 8.2.4 Proposals
- 8.2.5 Unsolicited Proposals and Capability Statements
- 8.2.6 RFPs and Proposals (Losers)

8.3 Small Purchasing

8.4 Vouchers

9. BUDGET PROGRAM

9.1 Program Memoranda

9.1.1 Program and Financial Plan

9.2 Program Proposals

9.2.1 Program Data Summaries

9.3 Departmental Review

9.4 Budget Submissions - NASA Review

9.5 Budget Submissions - OMB Review

9.6 Budget Submissions - Congressional Review

9.7 Budget Reports

10. RTOP

10.1 Ames Research Center

10.2 Flight Research Center

10.3 Goddard Institute for Space Studies

10.4 John F. Kennedy Space Center

10.5 Langley Research Center

10.6 Lewis Research Center

10.7 Lyndon B. Johnson Space Center

10.8 George C. Marshall Space Flight Center

10.9 Wallops Flight Center

ATTACHMENT B-2
SUSPENSE FILE

Recommended procedures for establishing and maintaining a Suspense File:

1. Label 12 file folders, one for each month. (Label is placed in the first position on the left of the folder).
2. Label 31 file folders, one for each day. (Label is placed in center of folder).
3. Day folders are placed in back of month folders.
4. Pending actions would be placed in folder for the day action is required.
5. The secretary should check the actions to be completed each day and notify the staff member responsible for completing the action.

GENERAL AVIATION ADVOCACY THEME

GENERAL AVIATION ADVOCACY THEME

September 1976

**National Aeronautics and Space Administration
Office of Aeronautics and Space Technology**

TABLE OF CONTENTS

	Page
HISTORICAL BACKGROUND	1
GENERAL AVIATION TECHNOLOGY	3
WHAT IS GENERAL AVIATION.....	5
GENERAL AVIATION CONSISTS OF A NUMBER OF DIVERSIFIED AIRCRAFT	7
USES OF GENERAL AVIATION.....	9
GENERAL AVIATION PRODUCTIVITY	11
GENERAL AVIATION IS BIG BUSINESS.....	13
GENERAL AVIATION, A WIDE RANGE OF TYPES, PERFORMANCE AND USE.....	15
ECONOMIC IMPACT OF GENERAL AVIATION	17
ECONOMIC BENEFITS OF GENERAL AVIATION	19
BENEFITS TO THE COMMUNITY	31
CONTESTED MARKET	39
THE IMPACT ON REMAINING U.S. ECONOMY	41
REQUIRED NASA ACTION	43
FINDINGS OF THE CARD STUDY.....	45
CURRENT ASSESSMENT OF PROBLEMS.....	47
AREAS WHERE G.A. NEEDS ASSISTANCE.....	53
PROBLEMS IN GENERAL AVIATION.....	59
NASA RESPONSE	65
CHANNELS FOR COMMUNICATION.....	67
NASA RESEARCH PROGRAM IN GENERAL AVIATION.....	69
APPENDIX A: GENERAL AVIATION TECHNOLOGY PROGRAM.....	A-1

HISTORICAL BACKGROUND

General Aviation (G.A.) has grown from humble surroundings to become a vital segment in this country's air transportation system. General Aviation links remote communities with large cities by providing air transportation to areas of this country that are not serviced by the airlines.

General Aviation predated the airlines by many years. In its early days, G.A., then known as private flying, consisted of townsmen setting up shop at the local airfield. These entrepreneurs performed a variety of services with the one or two light aircraft they owned. The aviation services they provided ran the gamut from carrying sightseers, performing aerial photography, mapping, and crop dusting, to teaching young airmen to fly. As the need for commercial transportation of people and goods increased, so did aviation.

Aviation grew rapidly, and in many directions. In 1926, the United States Government recognized the future potential of aviation, and took steps to regulate the use of the airways to best suit the needs of the nation and its people. The Air Commerce Act became law, and the Federal Government assumed full control and responsibility for operating and maintaining the national airways system. The Government enacted this law on the basis of public necessity—for the good of the entire nation. It was similar to what the Government had done to help develop other forms of transportation in the United States.

The concept of advocacy theme for G.A. has been proposed because G.A. is an area where technical advances will certainly benefit the nation.

GENERAL AVIATION TECHNOLOGY

ADVOCACY THEME:

- Redefinition of 10-year technology goal
- Ongoing G.A. R&T will be used as base
- Integration and demonstration programs

OBJECTIVES:

- Provide new technology for use in G.A. design
- Emphasize safety, efficiency and environmental compatibility of future aircraft
- Improve economic viability of G.A. operations.

GENERAL AVIATION TECHNOLOGY

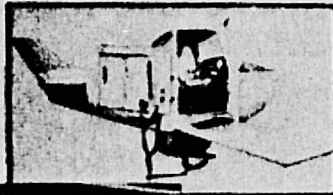
ADVOCACY THEME:

Development of the advocacy package for G.A. technology programs will concentrate on redefining the 10-year technology goal and identification of major areas of emphasis. Relatively constant discipline-oriented R&T base activities will be the basis for specific technology integration and demonstration programs addressing particular aircraft types.

OBJECTIVES:

To provide new technology for use in G.A. that will permit the design of future aircraft that are safer, more efficient and environmentally compatible.

WHAT IS GENERAL AVIATION?

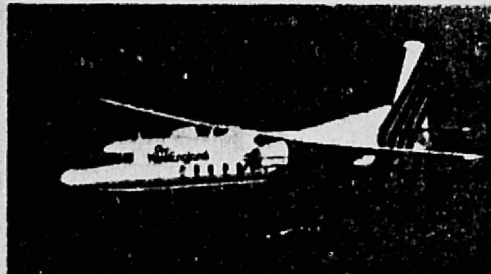


SIMULATOR

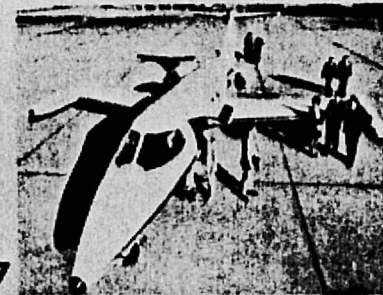


CLASSROOM

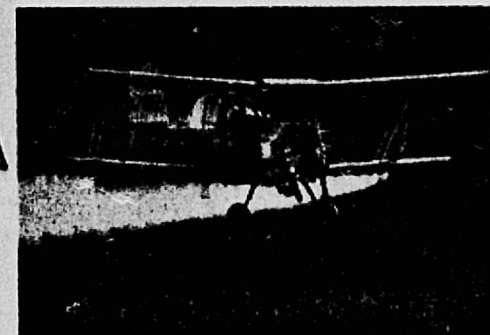
TRAINING



COMMUTER (AIR TAXI)



BUSINESS



AGRICULTURAL AVIATION

**ALL CIVIL AVIATION
ACTIVITY EXCEPT
CERTIFIED ROUTE
AIR CARRIERS**

WHAT IS GENERAL AVIATION?

OVERVIEW

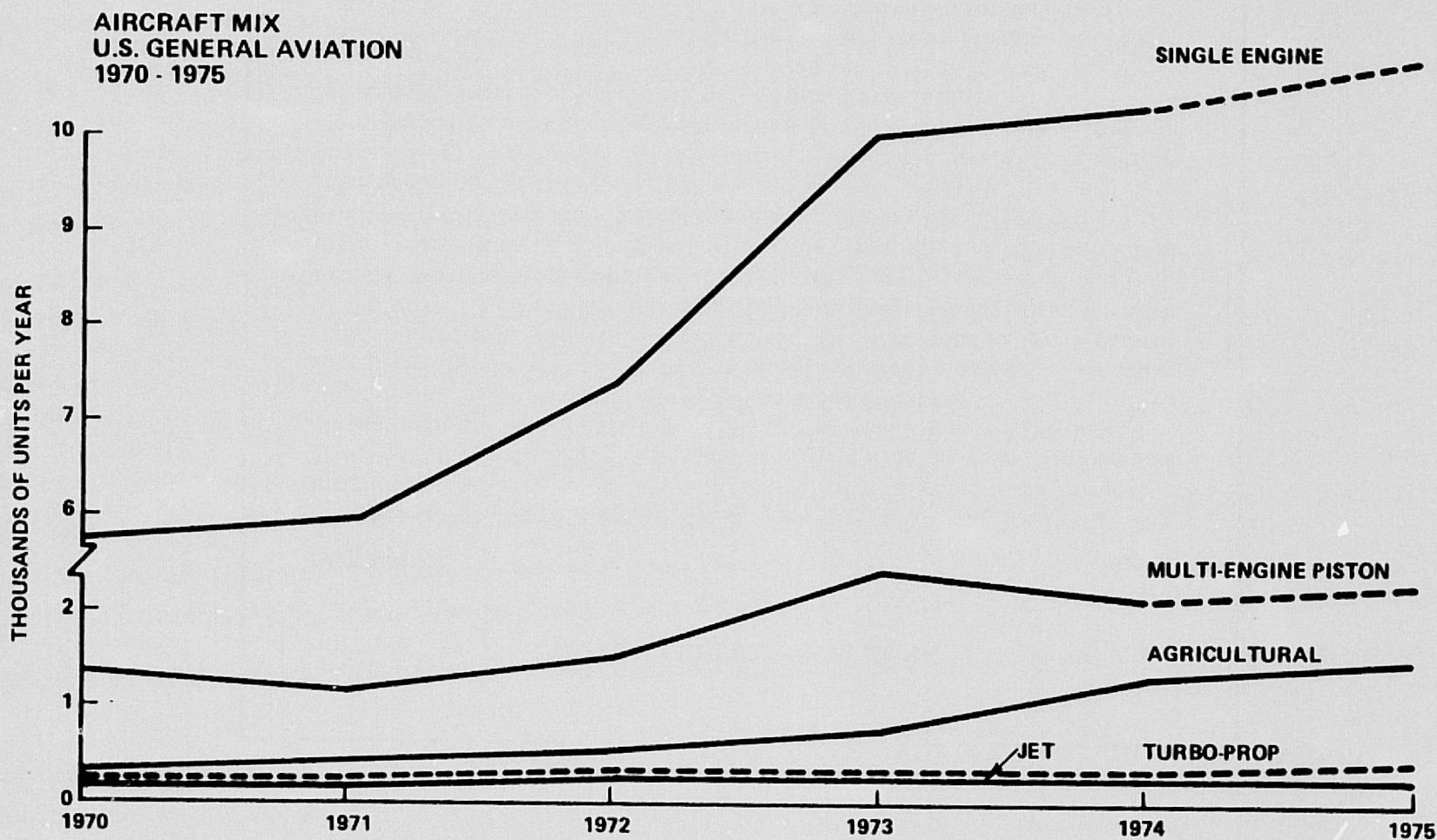
The broad classification of flying, identified as General Aviation (G.A.), includes all Civil Aviation activity except that of certificated route air carriers. The types of aircraft used in G.A. activities cover a wide spectrum, from corporate multi-engine jet aircraft piloted by professional crews, to amateur-built, single-engine piston acrobatic planes, balloons and dirigibles.

Presently, the active G.A. fleet accounts for over 98 percent of all active civil aircraft registered in the United States.¹ The fleet accounts for 79 percent of the current 57.7 million operations (landings and takeoffs) at airports with Federal Aviation Administration (FAA) traffic control service. In addition, there are an estimated 65 million G.A. aircraft operations at 12,000 public and private airports without FAA control towers. During the 1974-1986 period, total operations at airports with FAA traffic control service are expected to increase from 56.8 million to 123.4 million. At the same time, G.A. operations are expected to increase from 44.6 million to 106.6 million, thus accounting for about 93 percent of the growth in total aircraft operations.²

¹ As of December 31, 1973, the total active civil aircraft fleet numbered 156,207 aircraft, G.A. aircraft numbered 153,540—98.3 percent of the total fleet.

² DOT, FAA—AVP-75.4, *The General Aviation Industry: An Overview*.

GENERAL AVIATION CONSISTS OF A NUMBER OF DIVERSIFIED AIRCRAFT



GENERAL AVIATION CONSISTS OF A NUMBER OF DIVERSIFIED AIRCRAFT

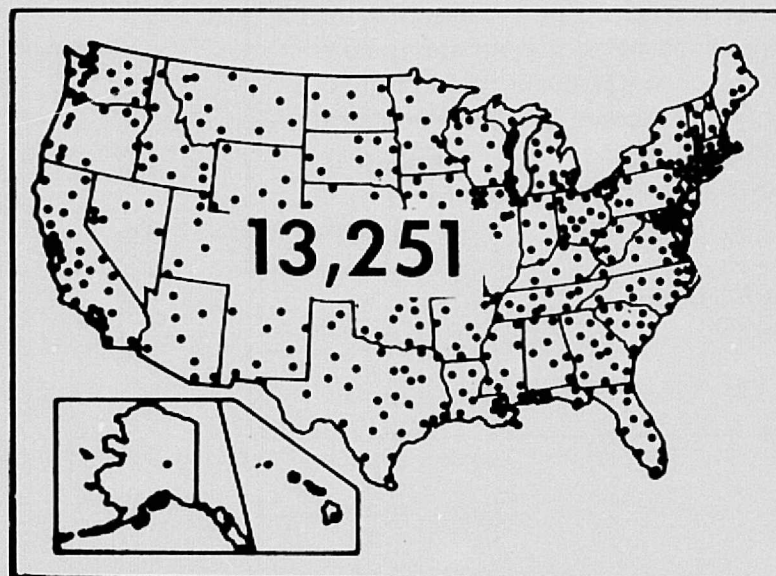
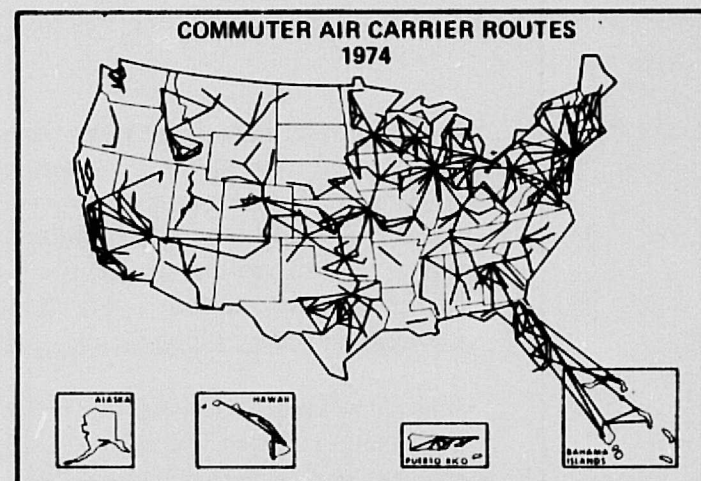
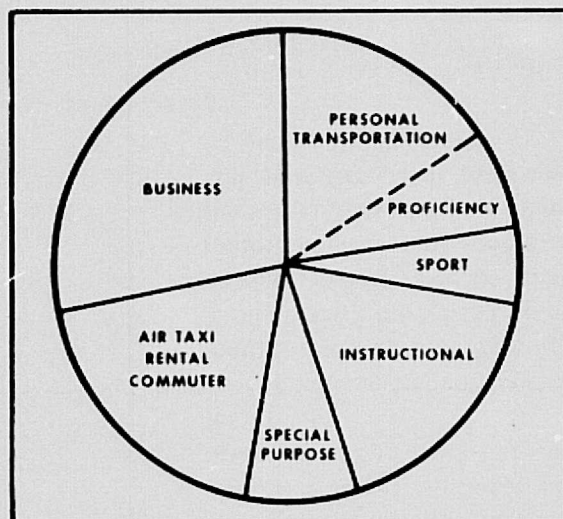
In 1974, the G.A. manufacturers shipped a total of 15,010 aircraft valued at \$909.4 million. Approximately 30 percent of these aircraft were exported. Each year, over 90 percent of the "free world" production of G.A. aircraft is built by U.S. manufacturers. The production trend is quite volatile because aircraft production is subject to changes in general economic conditions and in the business and financial outlook of prospective producers and purchasers of G.A. aircraft.

The G.A. manufacturing industry is dominated by three firms—Cessna, Beech, and Piper. In 1975, these companies produced 84 percent of the new aircraft shipped, and accounted for 66 percent of the net billing. Collectively, however, they accounted for less than 50 percent of the larger, more expensive, jet aircraft.

The industry employs 250,000 people.³ This includes direct and indirect manufacturing, fixed base operations, corporate flight departments, agricultural flying, etc. Fixed base operators provide a variety of services to G.A. These services include sale of fuel and aircraft components and airport and aircraft maintenance. Some operators act as dealers or distributors for the aircraft manufacturers, operate flight training facilities, and engage in other commercial activities, such as providing taxi services, aerial application and industrial or special flying services.

³ *The General Aviation Story*, General Aviation Manufacturers Association, Washington, D.C. 1974.

USES OF GENERAL AVIATION



USES OF GENERAL AVIATION

General Aviation flying has become increasingly important in recent years as a form of transportation for American businesses.

Business flying constitutes the largest segment of G.A. flying. It accounted for 1,433 million miles flown, 35 percent of G.A.'s 4,043 million total miles flown.

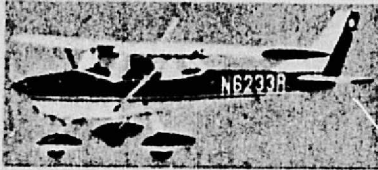
Instructional and personal flying are second in importance with 25 percent of hours flown in each category in 1974.

Commercial activities include air taxi and commuter airlines. These carriers fill a gap in the transportation system by providing the connecting links between the Nation's smaller and larger airports served by the air carriers. Commercial flying also includes industrial and agricultural uses and accounts for 19 percent of hours flown in 1974.

During the 1963-1973 period, the number of hours flown increased in all categories of G.A. activities. Instructional and personal flying tended to increase more than business and commercial flying, however.

PRODUCTIVITY

TRAINING: PROVIDES PRIMARY FLIGHT TRAINING



MILITARY

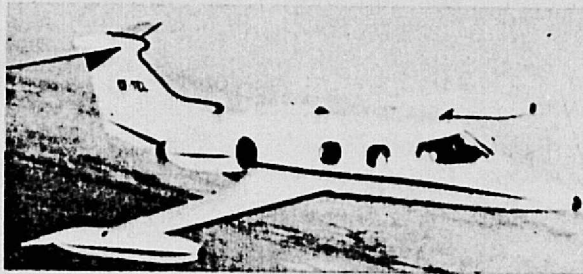


AIRLINES

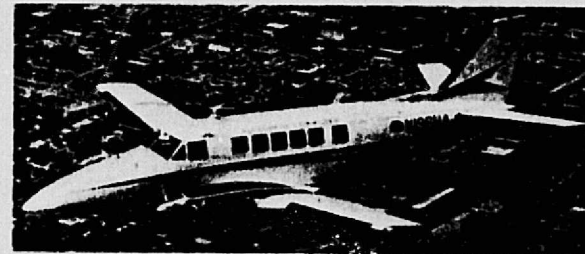


PRIVATE

TRANSPORTATION: ONE OF EVERY THREE INTERCITY AIR PASSENGERS

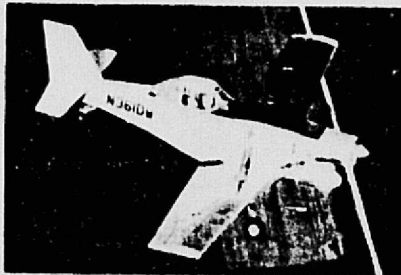


BUSINESS CORPORATE



COMMERCIAL

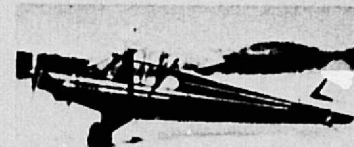
INDUSTRIAL: UNIQUE CAPABILITIES



APPLICATION



SENSING



SURVEY

NASA RA73-2038
2-26-73(3)

GENERAL AVIATION PRODUCTIVITY

TRAINING:

One of every four airline pilots in the United States comes directly from the ranks of G.A. And, most of those who switched from military to airline flying got their start in G.A. In effect, G.A. is a manpower pool for the future, just as it has been in the past. A sizable chunk of the number of pilots who guard our skies today, and who pilot the airlines come from G.A. backgrounds.

TRANSPORTATION:

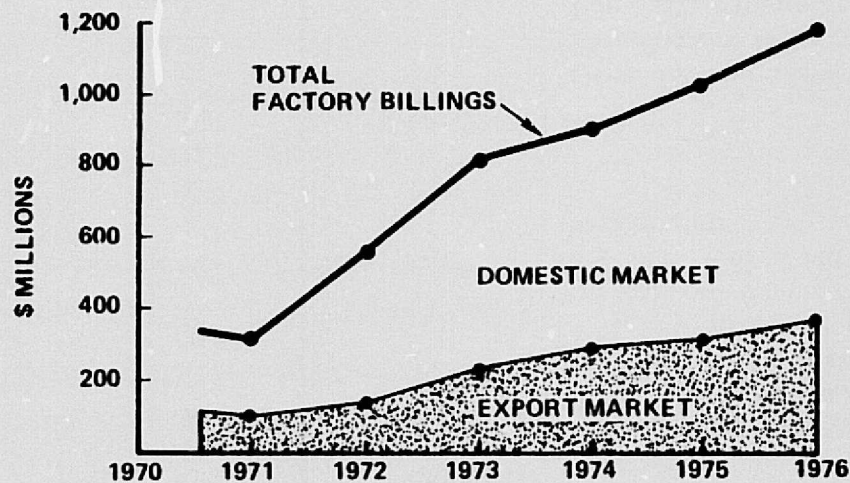
General Aviation serves 13,251 airports across the country. Over 96 percent of these are not served by the airlines. General Aviation aircraft transport 90 million intercity air passengers a year. By comparison, the airlines currently handle approximately 150 million intercity passengers.

INDUSTRIAL:

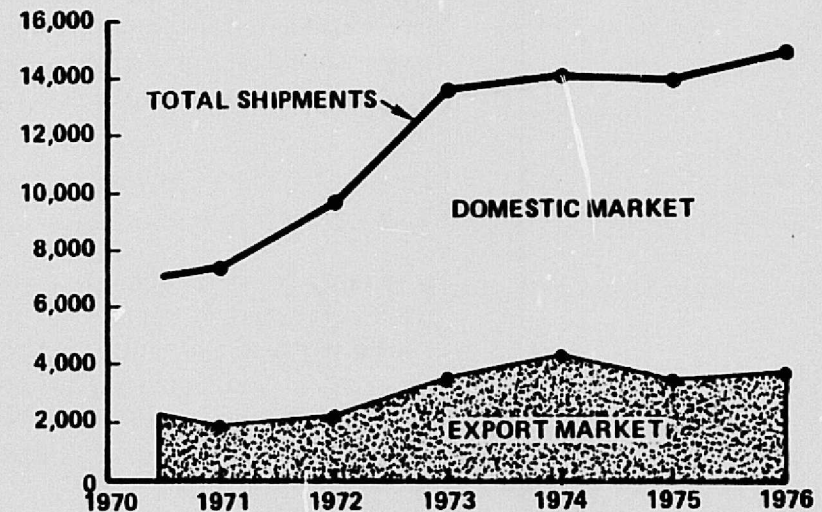
General Aviation aircraft have many unique industrial applications. The airplane is considered virtually irreplaceable in mapping, pipeline patrol and fire spotting.

GENERAL AVIATION IS BIG BUSINESS

GENERAL AVIATION \$ SHIPMENTS



GENERAL AVIATION UNIT SHIPMENTS



GENERAL AVIATION IS BIG BUSINESS

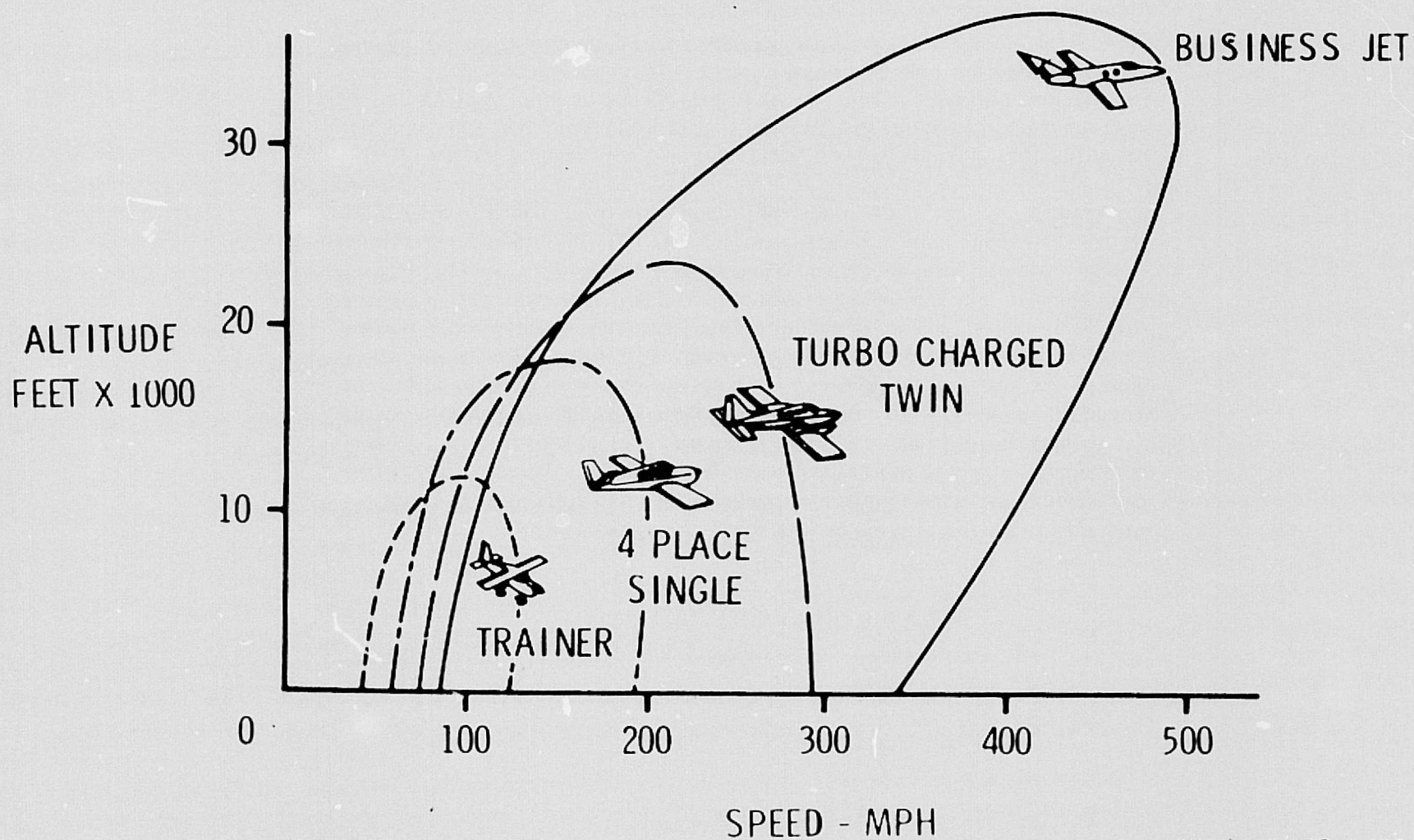
General Aviation contributes significantly to the U.S. balance of payments. For every G.A. aircraft imported in the U.S., manufacturers are exporting 23. In 1975, there were 14,072 units shipped with a value of \$1,032.6 million, at an average unit cost of \$73,402. Edward W. Stimpson, the GAMA president, predicted that in 1976 approximately 15,000 units would be shipped with factory billings amounting to approximately \$1.2 billion. Stimpson said "The assumptions supporting our industry forecast include continuing economic recovery, favorable business investment climate, continued expansion in the international market despite discriminating tariff and non-tariff barriers, and no escalation in federal regulatory constraints." He added that the long-term trend of G.A. is of substantial growth, with the industry experiencing a compounded annual rate of growth of 6 percent in units and 14 percent in dollar billings for the last 20 years.

Frost and Sullivan, Inc.* in their study on G.A. are even more optimistic. They predict that production of G.A. aircraft will climb 140 percent to \$2.4 billion by 1983, with an average cost of aircraft unit at \$101,000, and that output of single-engine, twin-engine piston, turboprop and business jet aircraft should exceed 24,000 units annually in 1983.

**The General Aviation Aircraft and Associated Avionics and Instrumentation Market (1973-1984), Frost and Sullivan, Inc., New York, N.Y.*

GENERAL AVIATION

A WIDE RANGE OF TYPES, PERFORMANCE AND USE



NASA RA72-1092

GENERAL AVIATION, A WIDE RANGE OF TYPES, PERFORMANCE AND USE

By 1983, the Frost and Sullivan study adds that shipments of:

1-3 place single engine	will rise to	6,779 units
4-plus place single engine	will rise to	13,173 units
twin-engine pistons	will rise to	3,260 units
twin-engine turboprops	will expand to	592 units
twin-engine business jets (under 20,000 pounds)	will expand to	290 units
twin-engine business jets (over 20,000 pounds)	will decline to	40 units

Higher purchase prices, financing costs and much higher operating costs are inhibiting the growth of the jet. In addition, the report identifies a shift in G.A. application-utilization taking place showing a decline in aircraft used for instructional purposes and personal transportation whereas usage in business and commercial markets will increase.

DIRECT ECONOMIC IMPACT OF GENERAL AVIATION
Millions of Constant Dollars

Value of Production	1967 ¹	1975 ²	1980 ¹
Domestic Sales of Aircraft	\$ 475.3	\$ 724.1	\$1,660.6
Exports of Aircraft	76.5	307.9	253.6
Avionics	45.7	69.5	159.8
Exports of Engines & Avionics	70.0	281.7	232.0
Transaction Costs of Used Aircraft			
Sales	22.0	34.9	86.0
User Costs	683.1	1,345.0	2,488.0
Pilot Wages & Administration			
Overhead	521.0	1,415.2	1,139.0
Value of Net Investment Producers	66.0	138.3	230.6
Distribution	25.1	44.7	68.8
FBO	31.8	62.6	115.8
Government Expenditures	218.0	599.0	695.5
Total Direct Economic Impact	\$2,234.5	\$5,022.9	\$7,129.7

The indirect economic benefits of business and personal flying have been estimated at approximately one-half the direct³ benefits or approximately \$2.5 billion for 1975.

¹ Speas Associates, *The Magnitude and Economic Impact of General Aviation, 1968-1980*.

² ORI Analysis.

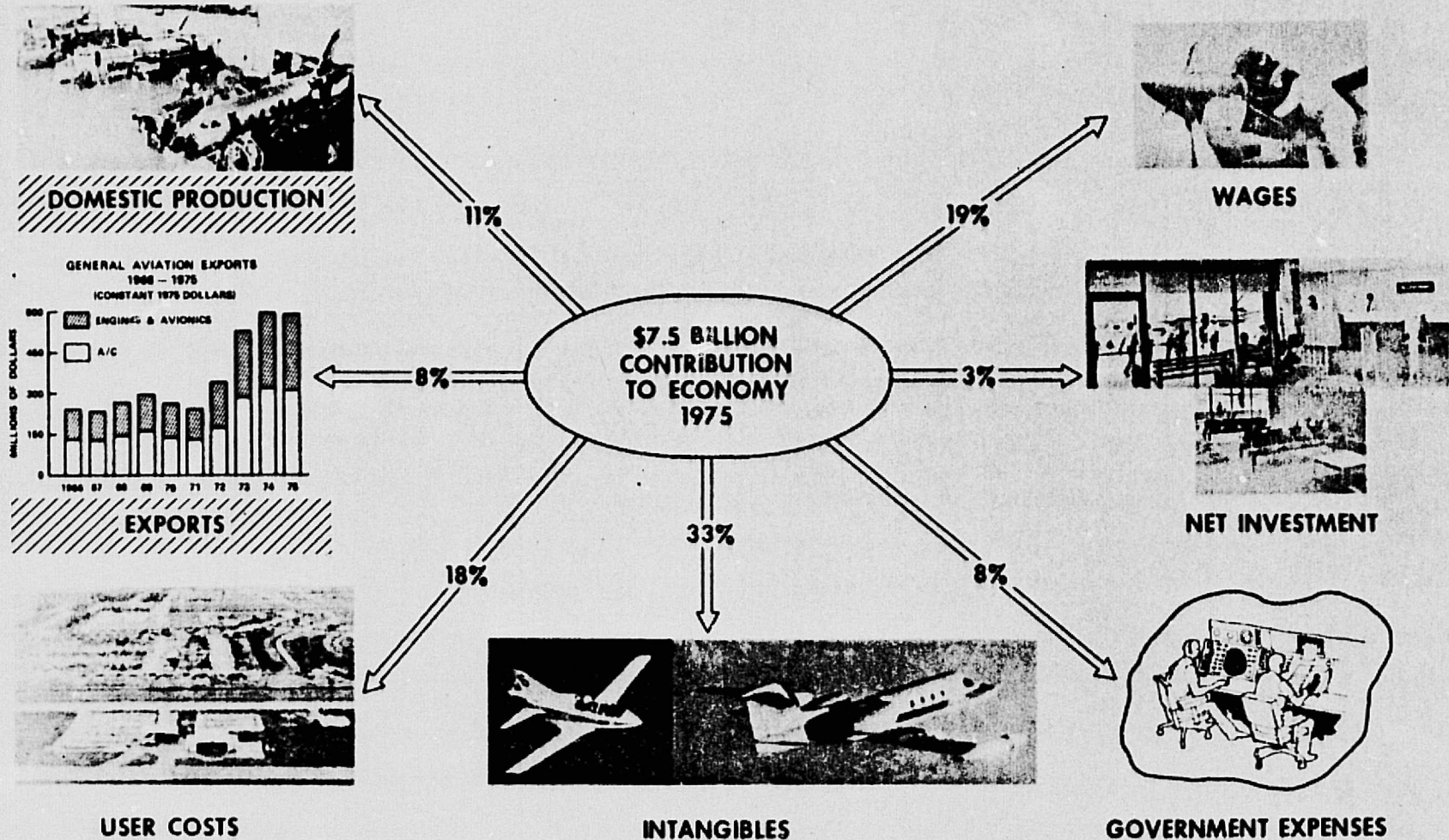
³ United Research, Inc., *Criteria for Federal Aviation Agency Expenditure*.

ECONOMIC IMPACT OF GENERAL AVIATION

To demonstrate the extent to which G.A. is big business, a summary table of the Direct Economic Impact of General Aviation is presented on the opposite page. The values given are the results of a 1967 study by Speas Associates.⁴ However, the figure for 1975 has been reconstructed by ORI using the Speas methodology in Chapter 8 of the study and GNP deflators to arrive at constant dollars for 1975.

⁴R. Dixon Speas Associates, *The Magnitude and Economic Impact of General Aviation, 1968-1980*.

ECONOMIC BENEFITS OF GENERAL AVIATION



ECONOMIC BENEFITS OF GENERAL AVIATION

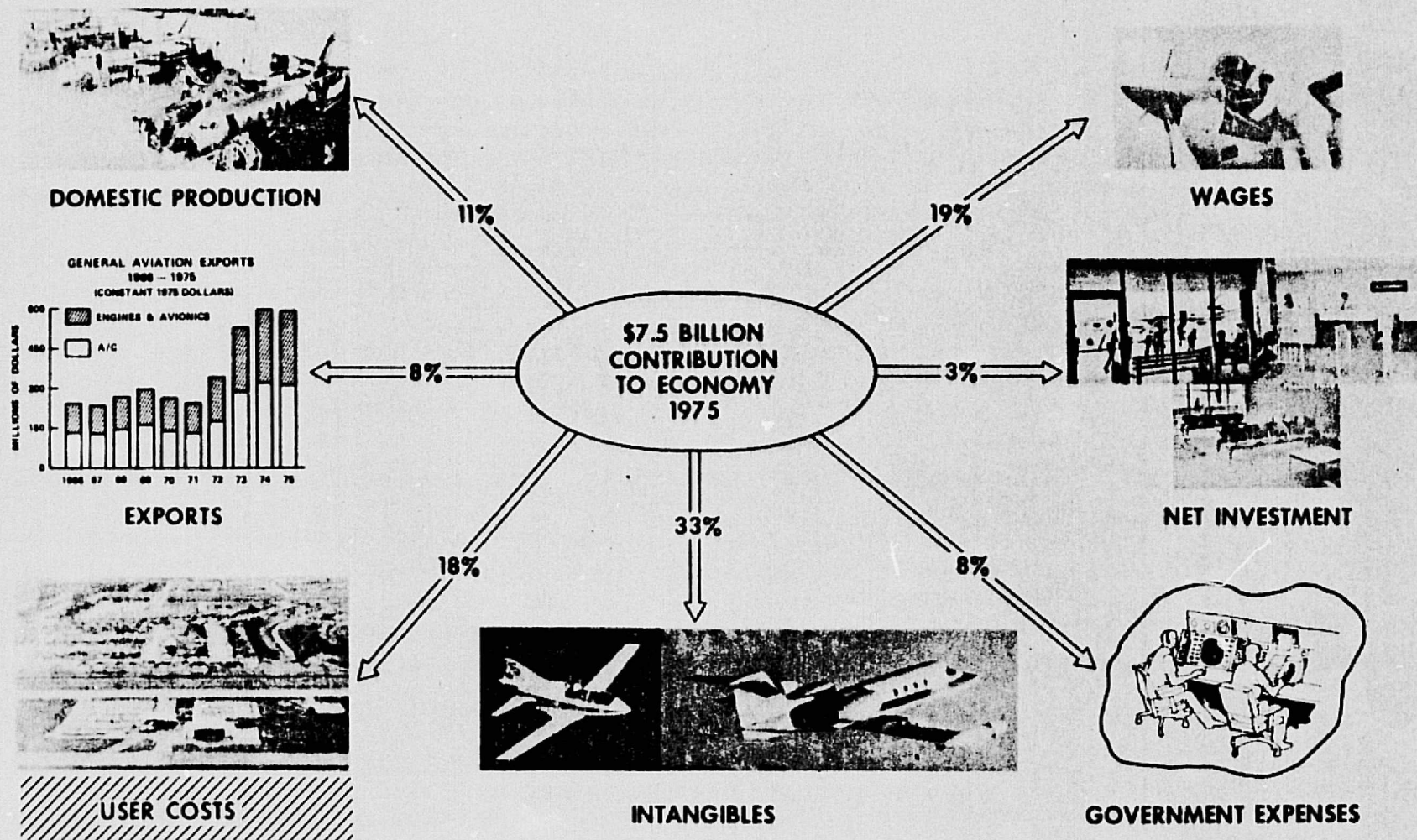
DOMESTIC PRODUCTION

In 1975, civil aircraft production declined for the first time in the seventies. Shipments for the 12-month period totaled 14,072 units, down 0.7 percent from 14,166 units delivered in the corresponding period in 1974. However, manufacturer's net billing price increased to \$1,032,584.4 because of inflation. GAMA president, Edward W. Stimpson, forecasts that 1976 shipments will reach 15,000 units with factory net billings amounting to \$1.2 billion. Since year-to-date unit shipments totaled 8,111 with net billings of \$598.7 million for the first six months of 1976 it would appear that the forecast will be reached.

EXPORTS

Aerospace exports reached record highs and contributed substantially to the U.S. balance of trade in 1975. Exports for the year totaled \$7.8 billion. However, year-end export shipments of G.A. aircraft totaled 3,513 units, down 17.3 percent from 4,248 units exported in 1974. Net billings for export shipments rose 7.1 percent to \$307 million from \$287 million reported in 1974. Export shipments accounted for 25 percent total production and 30 percent of total factory net billings during 1975. Export declines were due to tariff and non-tariff barriers and worldwide recession, especially in Western Europe. Preliminary year-to-date export shipments for the first half of 1976 totaled 1,886 units with factory net billings of \$170.6 million, up 4.6 percent and 11.4 percent, respectively, from the first half of 1975.

ECONOMIC BENEFITS OF GENERAL AVIATION



USER COSTS

User cost of aircraft operation include fuel and oil consumption, labor and parts, insurance, storage landing fees and other miscellaneous items. However, aviation user taxes are a fixed cost and currently air carriers and the administration are at odds over proposals to reduce such taxes which are funnelled into the Airport and Airways Trust Fund, presently showing a surplus of about \$1 billion.

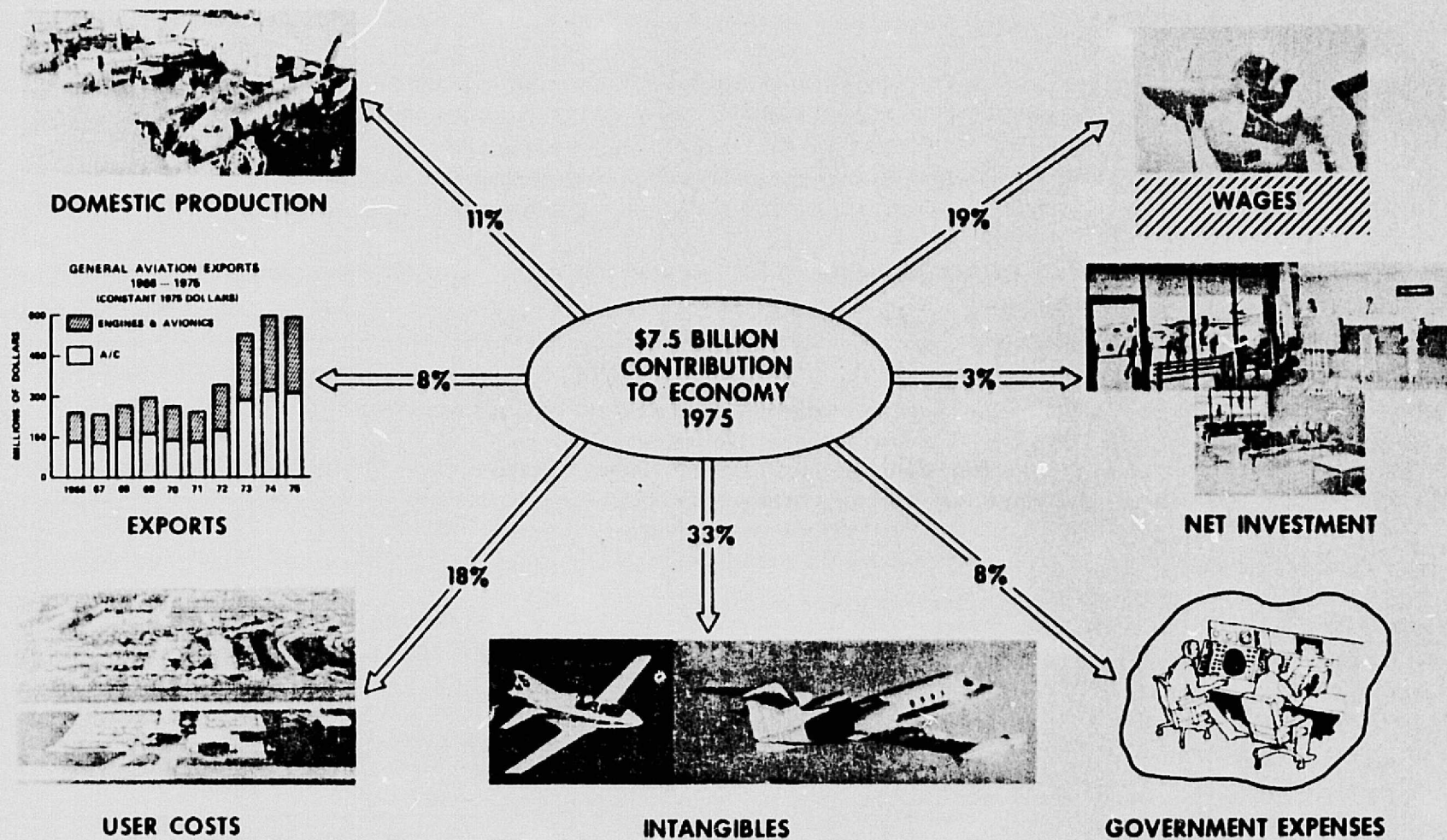
The taxes for G.A. are as follows:

\$25.00	annual registration tax per aircraft
0.07	aviation fuel tax per gallon
0.02	weight tax per pound for non-turbined aircraft
0.035	weight tax per pound for turbined aircraft
0.05	excise tax per pound on tires
0.10	excise tax per pound on tubes

	FY 1975	FY 1976 (estimated)
	(millions of dollars)	
Fuel	\$51.7	\$57.3
Registration	3.7	4.2
Aircraft Weight Fees	3.5	4.7
Tires and Tubes	.07	.075
	<u>\$58.97</u>	<u>\$66.275</u>

Source: FAA

ECONOMIC BENEFITS OF GENERAL AVIATION



WAGES

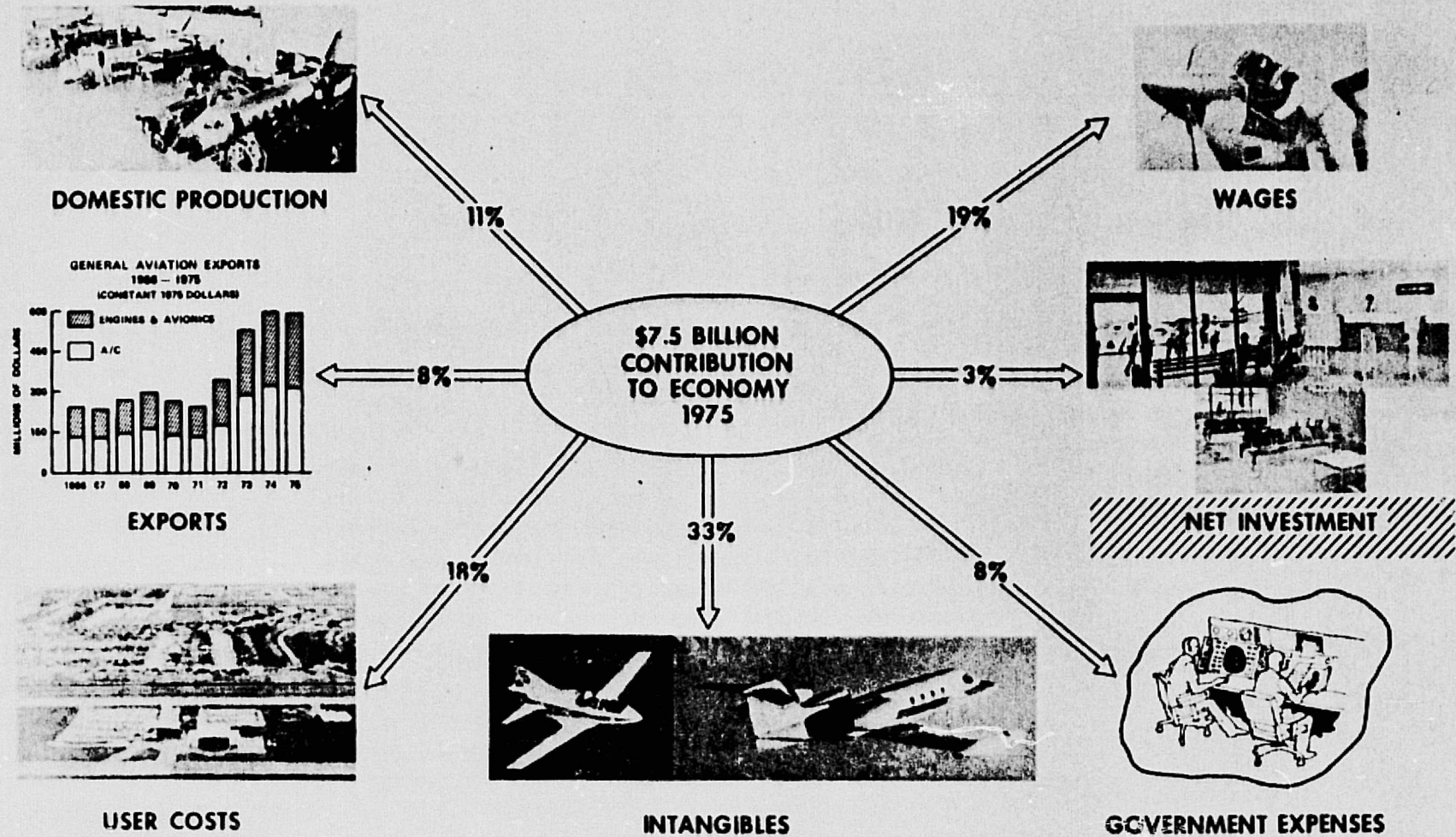
General Aviation employment includes 70,000 people in sales and service support for air commuter operation, flight training, maintenance, and other systems support. There are 25,000 engaged in agricultural flying, 35,000 in corporate flight departments, and 10,000 in industrial special uses, such as pipeline patrol, aerial mapping, and pollution control. Fifty thousand people are directly employed in the manufacturing of major G.A. components from airframes and engines to instruments. Self-employed instructors and mechanics number 10,000. Fifty thousand others are engaged in the manufacture of sub-components that go into G.A. aircraft, such as brakes, tires, wheels, wires, gas and oil.⁵

For the total of 250,000 employees, even at an average annual earnings per full-time employee in the Air Sector of \$13,936 (1973),⁶ the total amount earned is approximately \$3.5 billion.

⁵ *The General Aviation Story*, GAMA

⁶ *Summary of National Transportation Statistics*, DOT, June 1975, pg. 71.

ECONOMIC BENEFITS OF GENERAL AVIATION



NET INVESTMENT

There are two types of investment: fixed plant and equipment, and working capital. Plants generally have a 40 to 50 year life and equipment is generally depreciated over an 8 to 15 year life. Therefore, labor, material and component costs in a given year are much greater than fixed capital expenditures.

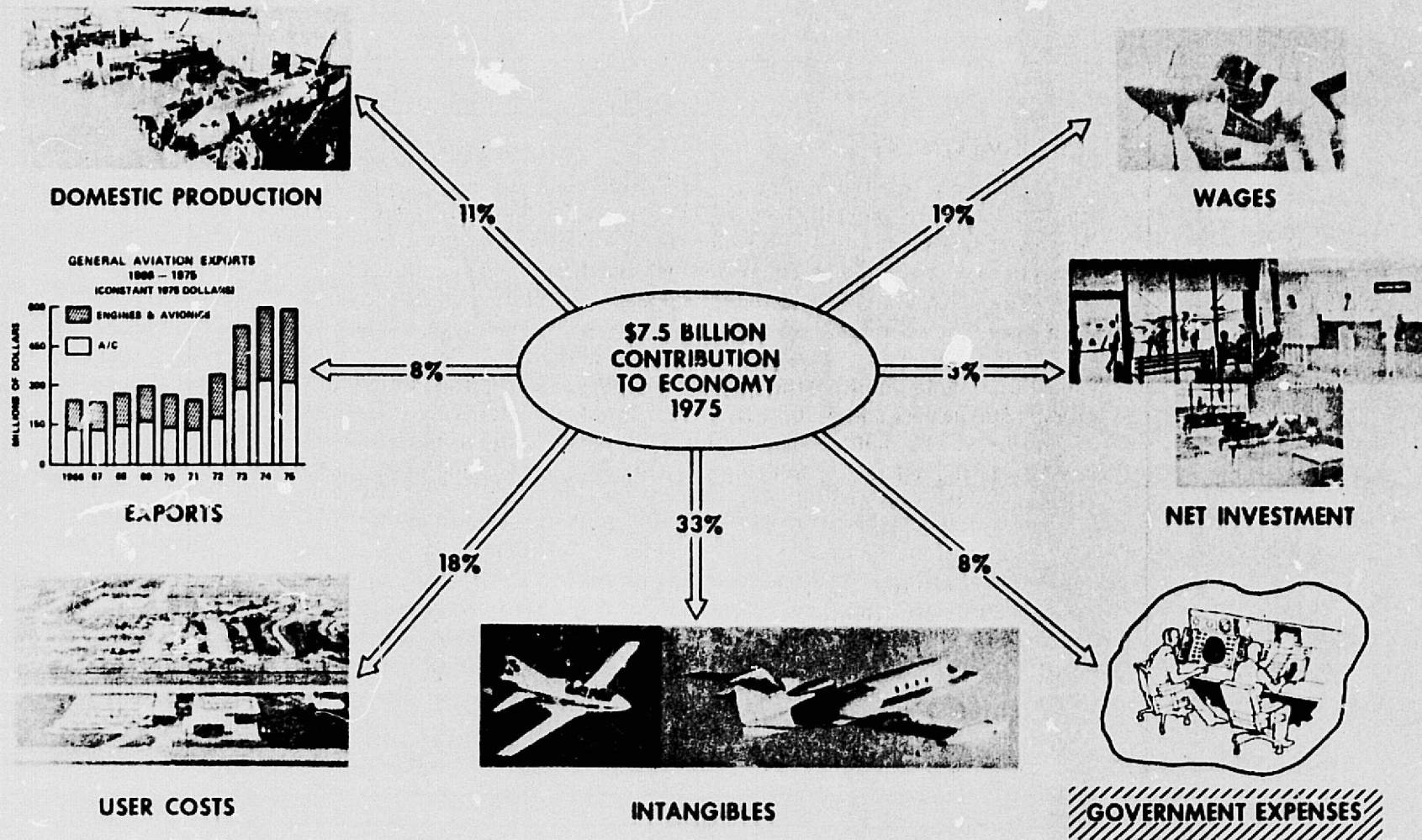
The Speas Study considered investment by producers, dealers, distributors and fixed base operators.

Capital asset data were taken from annual reports of Beech, Cessna, Piper and Lear Jet. In addition, the estimated total capital investment of 70 distributors, 1,500 dealers and 5,300 FBO's was considered in arriving at the FY 1967 figure of \$122.9 millions of constant dollars. The *value of net investment for 1975* was figured in the following percentages of the value of production in millions of 1975 constant dollars.

Value of Production: \$1,383.2 million

Producers (10% of Production)	138.3
Distributors (3.23% of Production)	44.7
FBO's (4.655% of User Costs)	<u>62.6</u>
Total	\$ 245.6 million

ECONOMIC BENEFITS OF GENERAL AVIATION



GOVERNMENT EXPENSES

Government spending on G.A. generates economic activity. On June 30, 1975, the FAA completed five years of airport development funding under the Airport Development Aid Program (ADAP). Funds were approved for 2,434 projects which included 906 at G.A. facilities.

Various aspects of the funds obligated in the ADAP program follow.

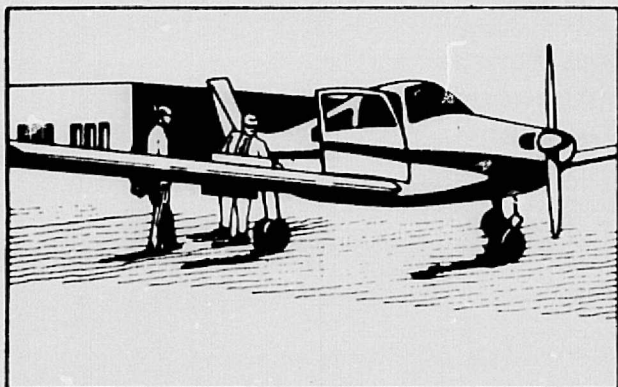
ADAP SUMMARY—FY 1971-1975

<u>Program</u>	<u>No. of Projects</u>	<u>No. of Airports</u>	<u>Federal Funds (millions of \$)</u>
Air Carrier	1,528	520	\$1,090.0
General Aviation (non-reliever)	757	624	151.2
General Aviation (reliever)	149	81	61.6
Total General Aviation	<u>906</u>	<u>705</u>	<u>212.8</u>
Grand Total	2,434	1,225	\$1,302.8

Source: DOT, FAA: Sixth Annual Report of Operations Under the Airport and Airway Development Act.

INTANGIBLE BENEFITS OF GENERAL AVIATION

G.A. ENABLES TIME SAVINGS OVER ALTERNATIVE MODES



FOR BUSINESS/CORPORATE FLYING THIS MEANS:

- GREATER USEFULNESS OF TRAINED, EXPERIENCED EXECUTIVES
- EFFICIENT COMMUNICATIONS BETWEEN HEADQUARTERS AND PLANTS MAKES DECENTRALIZED PRODUCTION
- MARKET AREAS MAY BE EXPANDED DUE TO MORE EFFICIENT USE OF MANAGEMENT AND SALES EXECUTIVES

FOR PERSONAL FLYING THIS MEANS:

- INCREASED FLEXIBILITY IN TRAVEL PLANS
- ENHANCED OPPORTUNITIES FOR EDUCATION THROUGH TRAVEL
- MORE RECREATION TIME AVAILABLE

INTANGIBLE BENEFITS OF GENERAL AVIATION

BUSINESS/CORPORATE:

- Fortune's top 500 industrials reported that 375 of them use business aircraft
- NBAA estimates that its more than 850 member companies generate about one third of the GNP
- Owners and users of business aircraft employ about one out of every eight workers in the nation's work force
- 91 of Fortune's 100 top industrial corporations operate their own aircraft. This group's productivity (sales per employee) is 15 percent better than others'.

FOR PERSONAL FLYING:

- Time savings by air increases quality of leisure
- Total trip costs are lower by air for the individual traveler who values his time
- Air travel trip costs for a family of four are lower than travel by train even if they place no value on time.

GENERAL AVIATION BENEFITS TO COMMUNITY

1. NEW INDUSTRY ATTRACTED

2. MANUFACTURING AND NON-FACTORY RELATED JOBS CREATED
3. EXPANSION OF LOCAL SERVICE INDUSTRIES ENCOURAGED
4. TAX BASE BROADENED BY NEW REAL PROPERTY TAXES
5. CAPABILITY FOR FAST AND FLEXIBLE TRANSPORTATION PROVIDED

BENEFITS TO THE COMMUNITY

A frequent misconception about airports is that they exist solely for the benefit of those who fly. The truth is that airports benefit everyone because they create new industry and new jobs, new money, and a broader tax base.

1. NEW INDUSTRY ATTRACTED

Cities and towns that 30 years ago decided they did not need airports have learned that this type of thinking jeopardizes community progress. Time and again the lack of an airport has proved to be the chief reason why a community has been bypassed as a location for a new plant or a new industry. Today, the airport industrial park complex is a new development in urban planning.

Motels, restaurants and rental car agency services are found at or near G.A. airports.

Light manufacturing companies dependent upon air carriers, air taxis and rental aircraft for transportation locate at or near airports.

Significant benefits have resulted to these four communities because of their G.A. airport.

- St. Paul, Minnesota: G.A. aircraft increased business volume to \$233 million/year, not otherwise available.
- Fort Lauderdale—Hollywood International Airport: the FAA control tower recorded 230,087 takeoffs and landings by G.A. aircraft in 1969—more than 600 a day. Each airplane carried an average of three and a half persons who spent \$50 a day during a week's stay. These visitors added nearly \$141 million to the local economy during 1969 at a rate of around \$300 a minute.
- Idaho Falls, Idaho: Fanning Airport supports 34 airport lessees who provide employment for 176 persons. Their annual salaries total \$758,000. Originally constructed in the 1920's, the airport now includes an airport industrial park. In 1969, airport activity produced an annual cash flow of \$4.4 million. Local expenditures by airport lessees in 1969 amounted to \$1.2 million, while direct income from lessees was \$80,312. Local expenditures by air travelers totaled \$2.4 million.
- Long Beach, California: Chamber of Commerce reported that in 1968, transient aircraft alone generated spending of \$9.8 million. Of that total, \$3,239,940 was spent for airport services. The city's hotels and motels received \$1,079,980; restaurants, \$981,800; and general merchants, \$3,436,300.

GENERAL AVIATION BENEFITS TO COMMUNITY

1. NEW INDUSTRY ATTRACTED

2. MANUFACTURING AND NON-FACTORY RELATED JOBS CREATED

3. EXPANSION OF LOCAL SERVICE INDUSTRIES ENCOURAGED

4. TAX BASE BROADENED BY NEW REAL PROPERTY TAXES

5. CAPABILITY FOR FAST AND FLEXIBLE TRANSPORTATION PROVIDED

2. MANUFACTURING AND NON-FACTORY RELATED JOBS CREATED

The extent an airport influences the local economy varies with the size and location of the community. New jobs generated by the airport result in increased economic prosperity for the community.

Operation of an airport requires a variety of services, e.g., supplying aviation fuel, aircraft sales and maintenance, and operating concessions. A Fixed Base Operator (FBO) is a retail firm that sells G.A. products or services to an airport. Sometimes the FBO conducts the actual management, operation and maintenance of the airport, employing one, two, or as many as a hundred persons. FBO services include aircraft airframe, engine and/or instrument repairs; flight training; air taxi service and charter flights; aircraft sales; fuel and parts; and aircraft exterior and/or interior modification. Job requirements in such an operation call for aviation mechanics, flight instructors, and aircraft salesmen.

Other airport employees include servicemen who maintain the runways, operate snow removal equipment, and maintain various electrical systems. Administrative clerks, typists, and secretaries are needed in the offices of an FBO or airport manager. Concessions offer a wide range of jobs, e.g., restaurants, newsstands, gift and book shops, and car rental agencies. Once a community can support scheduled air carrier service, job opportunities expand as an increase of air travelers requires more and varied services.

The real impact of new job opportunities on a community is reported by a U.S. Chamber of Commerce study showing that 100 jobs create:

- \$710,000 increased personal income
- \$331,000 more retail sales
- 97 more passenger cars registered
- 3 new retail establishments
- 65 more employees in non-manufacturing jobs
- population increase of 359 persons

GENERAL AVIATION BENEFITS TO COMMUNITY

1. NEW INDUSTRY ATTRACTED
2. MANUFACTURING AND NON-FACTORY RELATED JOBS CREATED
3. EXPANSION OF LOCAL SERVICE INDUSTRIES ENCOURAGED
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5. CAPABILITY FOR FAST AND FLEXIBLE TRANSPORTATION PROVIDED

3. EXPANSION OF LOCAL SERVICE INDUSTRIES ENCOURAGED

Existing local industry benefits because an airport facilitates communications with customers, suppliers, and technical sources to improve operations and even expand manufacturing output.

Retail establishments, banks and services enjoy increased business from a larger population and more personal income.

Airports also generate revenue from transient purchasers. Stop-overs by all type air travelers bring new money into the community. Motels, hotels, restaurants, fuel suppliers, gift shops, auto rental agencies, stores, and services of all types do more business, thus employ additional people, and spend more with local suppliers.

As the G.A. industry expands there is a growing trend to improve ground facilities for its accommodation.

4. BROADER TAX BASE

Development of new basic industry and expansion of local service industries is accompanied by revenue increases from new real property taxes. Some extra costs are incurred by the revenue authority to supply utilities, protection and other government services for business stimulated by the airport. However, studies indicate that R&D industries, light manufacturing, offices, and commercial activity require considerably less public expenditure than the property taxes they pay. As much as 40 percent of the taxes such businesses pay may be in excess of the governmental expenditures made necessary by their existence.

Example: The principal reason for an IBM decision to locate a \$15 million plant was existence of municipal airport at Manassas, Virginia. IBM pays \$209,000/year county and \$52,000/year town taxes.

GENERAL AVIATION BENEFITS TO COMMUNITY

1. NEW INDUSTRY ATTRACTED
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5. FAST AND FLEXIBLE TRANSPORTATION PROVIDED

Commuter air carriers and air taxi companies provide adequate and timely services where certificated carriers do not schedule sufficient flights or have abandoned scheduled services because of losses.

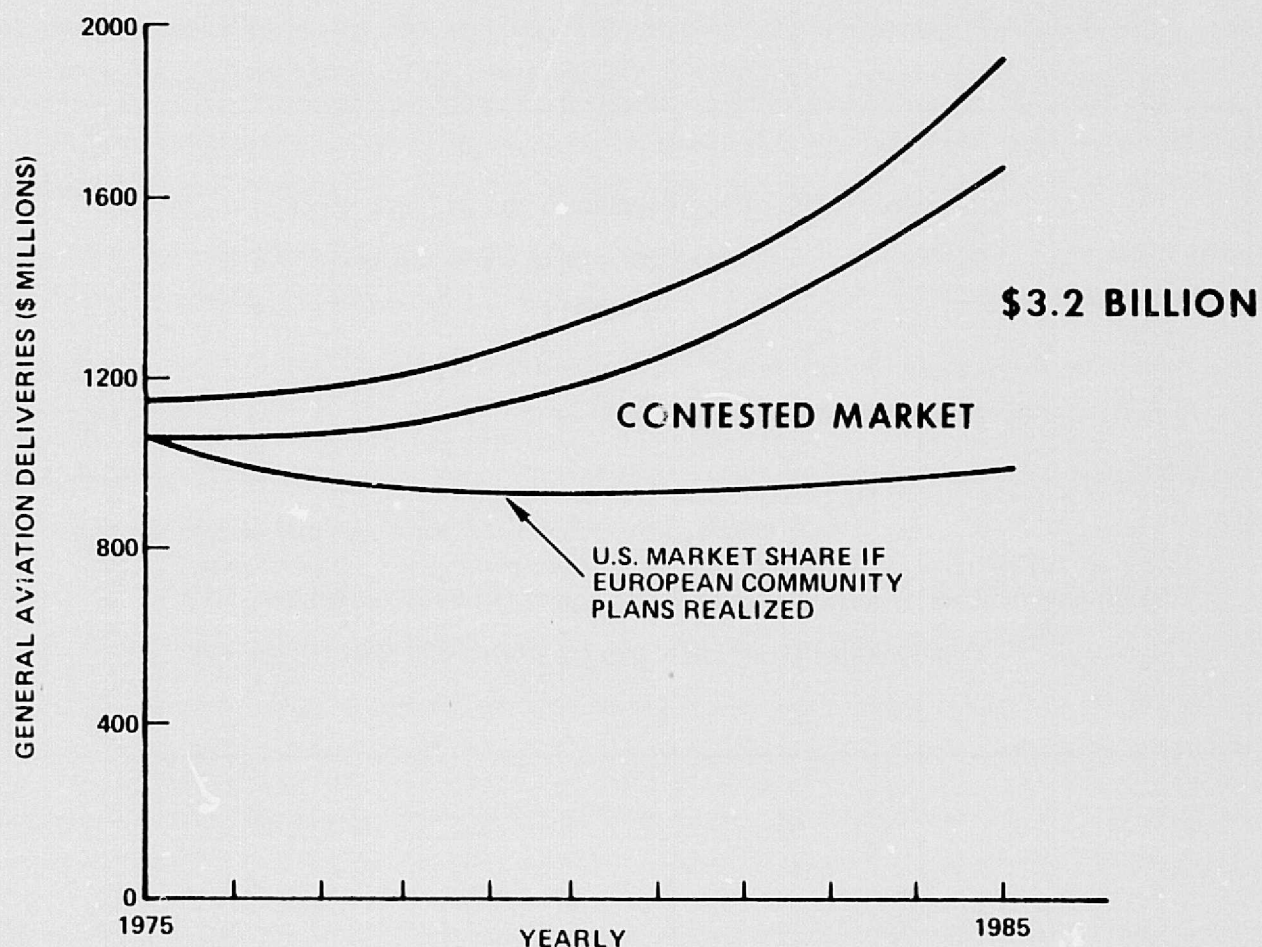
In FY 1975, 235 commuter airlines performed the following services:

- Served 747 airports
- Passengers — 6.6 million
- Mail — over 82,000 tons
- Cargo — 84,600 tons
- Made almost 1.5 million departures

In 1973, 3,000 air taxi companies flew 10 million passengers.

WORLD CIVIL GENERAL AVIATION MARKET

TOTAL WORLD MARKET - 10 YEARS - \$14.2 BILLION



WORLD MARKET FOR GENERAL AVIATION IS GROWING (RAPIDLY)

CONTESTED MARKET

The portion of the curve labeled "contested market" refers to the share of the world market in which a competitive situation between U.S. and foreign G.A. manufacturers will exist in the 1975-1985 period. This region is bounded by the current U.S. share of 90 percent of the world market, and the projected U.S. share that would result if the European Economic Community's plans were realized.

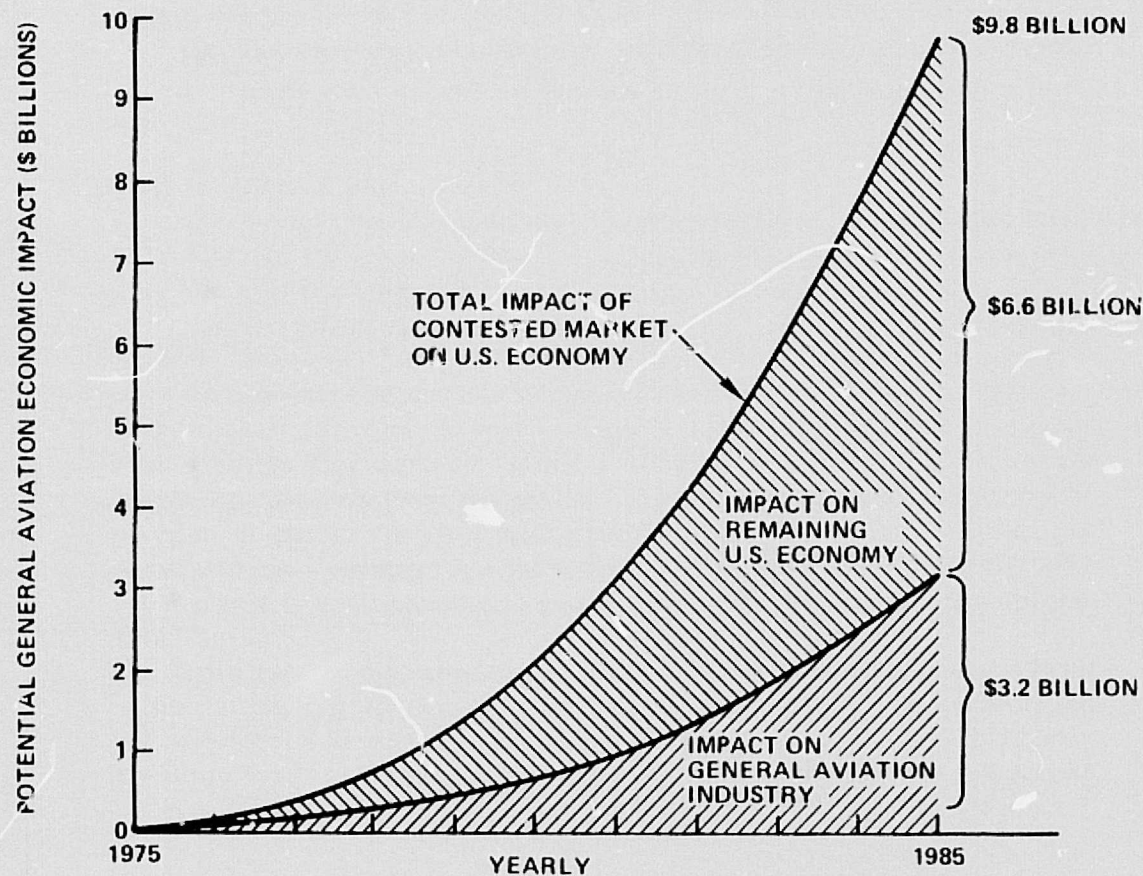
Lacking new technological advances in U.S. G.A. aircraft, the Europeans (as well as the Canadians and Japanese) are producing very competitive G.A. aircraft. If the EEC's plans are realized, the U.S. share of the world G.A. market will decrease from the 90 percent level of 1975 to approximately 50 percent of the 1985 market. If the Europeans capture a larger share of the world market, technological advances will enable them to enhance their credibility for producing dependable and reliable G.A. aircraft. Once this confidence factor is established, the Europeans will be in actual competition with U.S. manufacturers for the U.S. market.

The EEC is mounting an all-out offensive to compete with the U.S. for a larger share of the world aviation market. Although the EEC plan places major emphasis on transports, the indications are clear that G.A. is also a prime target. They are implementing their plans by:

- Requiring European users to buy European manufactured aircraft
- Subsidizing the aircraft industry in R&D as well as in manufacturing

The contested market ranges from 468 aircraft and \$34 million in 1976, to 10,800 aircraft and \$730 million in 1985. These are in 1975 constant dollars. Further, spare engines and avionics related to the contested market are evaluated at an additional potential loss of \$2.9 billion.

IMPACT OF CIVIL GENERAL AVIATION CONTESTED MARKET
GENERAL AVIATION INDUSTRY - 10 YEARS - \$3.2 BILLION
TOTAL U.S. ECONOMY - 10 YEARS - \$9.8 BILLION
CUMULATIVE 1976-1985



**CONTESTED CIVIL GENERAL AVIATION MARKET HAS
 ADVERSE IMPACT ON G. A. INDUSTRY AND U.S. ECONOMY**

THE IMPACT ON REMAINING U.S. ECONOMY COVERS
SUCH THINGS AS:

- Reduced sales of spare engines and avionics
- Reduced income associated with distribution of material
- Reduced spending for capital investments
- Zero growth in G.A. industry
- Loss of favorable trade balance.

REQUIRED NASA ACTION

TO ASSIST THE GENERAL AVIATION INDUSTRY IN MAINTAINING
ITS CURRENT FOREIGN MARKET SHARE, NASA MUST ADDRESS
KEY TECHNOLOGY PROBLEMS.

REQUIRED NASA ACTION

The 170,000 airplanes that comprise the G.A. fleet are used in a wide range of productive activities. In addition to recreational and sport flying, the use of the small airplane as a business tool and a means of transportation has grown to such an extent that it now touches nearly every segment of the nation's economy. Yet, as G.A. has grown to become a significant part of the nation's civil air transportation system, problems have emerged that are critical to the continued health and progress of this segment of the aviation industry.

The overall safety record must be improved. Aerodynamic efficiency while always a goal in aircraft design is far more important in light of the energy shortage. As with other modes of transportation, the light airplane must be made more compatible with the environment.

These problem areas are not new to G.A., rather they are either old problems on which no progress towards solutions has been made, or old sins finally catching up with us. Examples of the former case may be found by a review of the findings of the CARD Study.

THEN AND NOW

AIRPORTS & AIR TRAFFIC CONTROL
CONGESTION & EQUIPMENT COST
TO COPE WITH
IT MAY LIMIT G.A. GROWTH

SAFETY

- GREATER NUMBER OF OPERATIONS LEADS TO HIGHER NUMBER OF FATALITIES
- PROBLEM DIMENSIONS ON A/C, ITS SUBSYSTEMS, AIRMAN'S PROFICIENCY AND EXPERIENCE

- SAFETY – TECHNICAL SOLUTIONS REQUIRED TO SOLVE HIGH FATALITY RATE
- FOREIGN COMPETITION – FOREIGN GOVERNMENTS LIKELY TO ACT TO REVERSE BALANCE OF TRADE SITUATION
- ENVIRONMENTAL CONCERNS – EXCESSIVE A/C NOISE IS A MAJOR IMPEDIMENT TO AVIATION GROWTH
- ENERGY – G.A. IS ENERGY INEFFICIENT COMPARED TO MASS GROUND TRANSPORTATION
- COST – CONGESTION AND SOPHISTICATED AVIONICS WILL SUBSTANTIALLY IMPACT G.A. ACTIVITY AND GROWTH

FINDINGS OF THE CARD STUDY

Over five years ago, a joint NASA/DOT effort on Civil Aviation was completed. The findings were published in the "Civil Aviation Research and Development Policy Study" (CARD Study). This study projected that by 1985, private operators (all G.A. except commuter airlines) would account for 65 percent of the G.A. inventory and 50 percent of the hours flown. Further, that such large numbers of private planes in the air system, operated generally by pilots less skilled than commercial pilots, would pose a substantial load on air traffic control and airports in the future.

The study also predicted that unless there was a substantial improvement in operating and investment costs, and in utilization of personal aircraft, the market for personal aircraft would continue to be limited. This conclusion was based on the fact that purchase of a personal aircraft required an initial capital investment of at least from four to five times the cost of an automobile.

The specific problems called out in the study evolved around the following areas:

SAFETY:

- The gross number of fatalities has been due to the large increase in the number of operations
- The problem of safety in G.A. has two basic dimensions:
 - The aircraft and its subsystems
 - The airman's proficiency and experience.

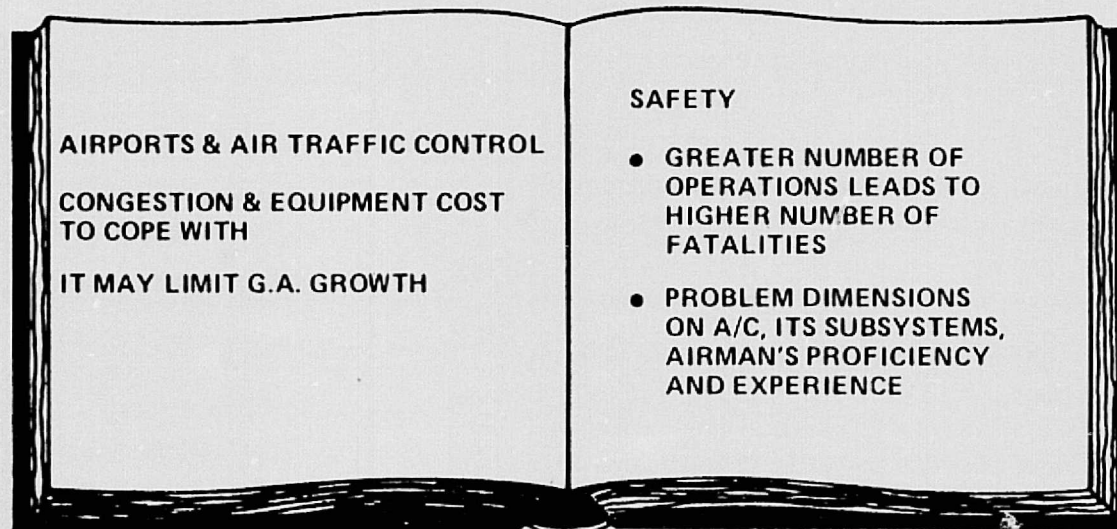
AIR TRAFFIC CONTROL:

- ATC systems selected and the regulations pertaining to their use, have considerable impact on the cost of private flying.

AIRPORTS:

- Many G.A. pilots prefer not to use the major airports because of the added cost of airborne equipment, their inexperience, or their uneasiness over operating in such a complex environment.

THEN AND NOW



- SAFETY – TECHNICAL SOLUTIONS REQUIRED TO SOLVE HIGH FATALITY RATE
- FOREIGN COMPETITION – FOREIGN GOVERNMENTS LIKELY TO ACT TO REVERSE BALANCE OF TRADE SITUATION
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CURRENT ASSESSMENT OF PROBLEMS

In recent Congressional testimony, Mr. F.A. Meister of FAA summed up his department's assessment of the current problems facing G.A. The current contingent of G.A. problems consists of the following:

SAFETY:

- General Aviation safety, although improved over the years, has a fatality rate which is much higher than that of the passenger automobile.
- Unless technical solutions are developed to improve safety; more regulations and growing inefficiencies may result.

FOREIGN COMPETITION:

- General Aviation manufacturers have built 90 percent of the free world fleet with 1975 production at 97-98 percent of the market
- Foreign governments will probably take some action to reverse their adverse balance of trade posture.

ENVIRONMENTAL CONCERNS:

- Excessive aircraft noise is a major impediment to aviation growth.

ENERGY:

- FAA's goal is to improve energy efficiency by 10 percent
- Although a small consumer of U.S. petroleum (about 6 percent of transportation fuel), G.A. is perceived as being energy inefficient in comparison with other common carrier transportation modes
- General Aviation has a bad public image.

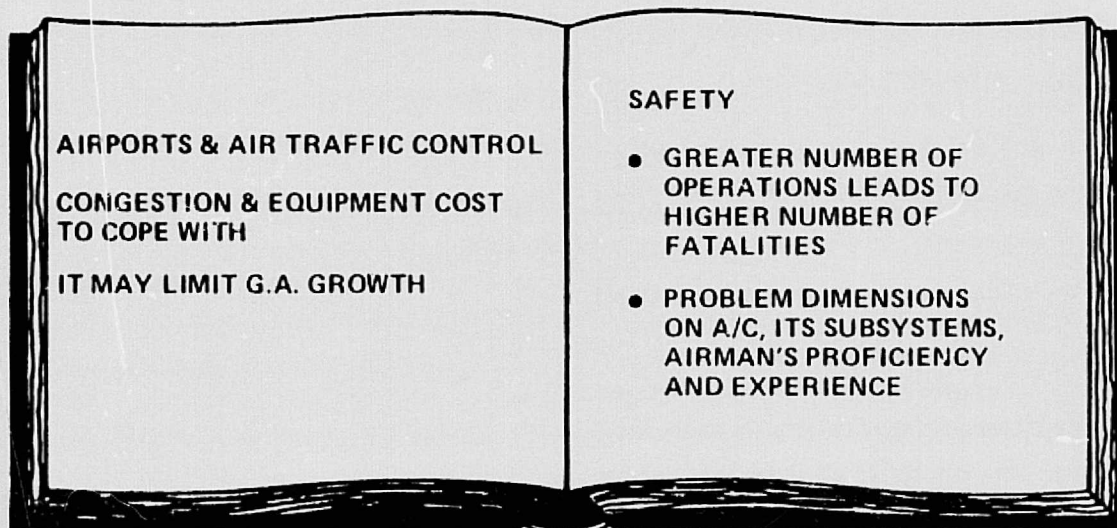
USER COSTS:

- Increasing congestion, fuel costs, avionics sophistication and the possibility of increased user charges will substantially impact on the nature and development of air traffic activity and growth.

HEALTH OF THE ECONOMY:

- Aviation growth is particularly sensitive to GNP
- A one percent change in GNP results in a 1.6 percent change in the G.A. fleet size and a 2.05 percent change in operations.

THEN AND NOW



- **SAFETY** – TECHNICAL SOLUTIONS REQUIRED TO SOLVE HIGH FATALITY RATE
- **FOREIGN COMPETITION** – FOREIGN GOVERNMENTS LIKELY TO ACT TO REVERSE BALANCE OF TRADE SITUATION
- **ENVIRONMENTAL CONCERNS** – EXCESSIVE A/C NOISE IS A MAJOR IMPEDIMENT TO AVIATION GROWTH
- **ENERGY** – G.A. IS ENERGY INEFFICIENT COMPARED TO MASS GROUND TRANSPORTATION
- **COST** – CONGESTION AND SOPHISTICATED AVIONICS WILL SUBSTANTIALLY IMPACT G.A. ACTIVITY AND GROWTH

CARD STUDY 1971

MEISTER CONGRESSIONAL TESTIMONY 1976

FACTORS AFFECTING GROWTH

SAFETY:

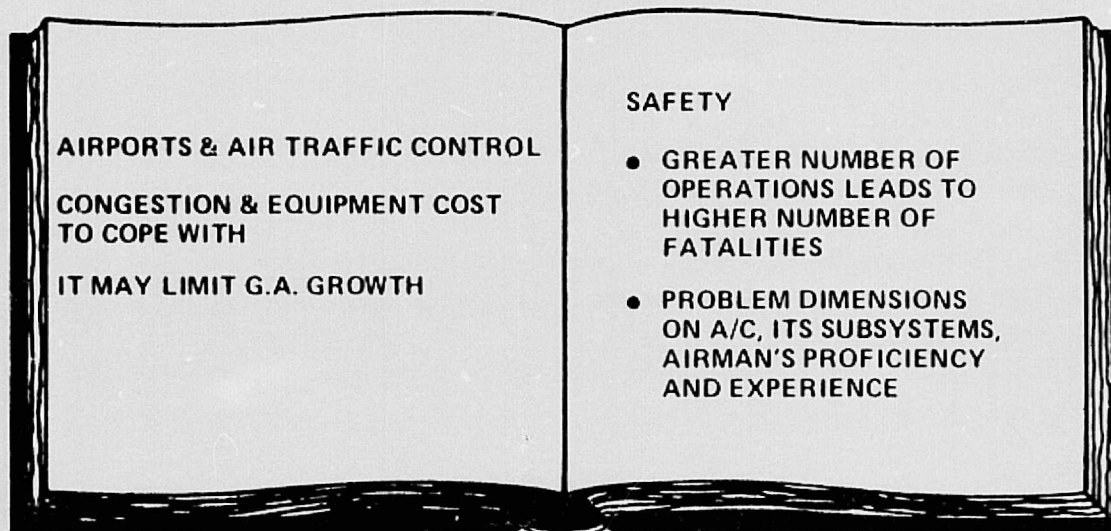
- General aviation safety requires substantial improvements
- Technological solutions needed or increasing regulation and system inefficiencies will result

FATALITY RATE PER 100 MILLION PASSENGER MILES

<u>Year</u>	<u>Domestic Scheduled Air Carriers</u>	<u>Railroad Passenger Trains</u>	<u>Buses</u>	<u>Passenger Automobiles and Taxis</u>	<u>U.S. General Aviation</u>
1949-51	1.26	0.36	0.21	2.87	47
1959-61	0.67	0.10	0.18	2.20	24
1972-74	0.12	0.22	0.21	1.63	19

THEN AND NOW

A Summary



- SAFETY – TECHNICAL SOLUTIONS REQUIRED TO SOLVE HIGH FATALITY RATE
- FOREIGN COMPETITION – FOREIGN GOVERNMENTS LIKELY TO ACT TO REVERSE BALANCE OF TRADE SITUATION
- ENVIRONMENTAL CONCERNS – EXCESSIVE A/C NOISE IS A MAJOR IMPEDIMENT TO AVIATION GROWTH
- ENERGY – G.A. IS ENERGY INEFFICIENT COMPARED TO MASS GROUND TRANSPORTATION
- COST – CONGESTION AND SOPHISTICATED AVIONICS WILL SUBSTANTIALLY IMPACT G.A. ACTIVITY AND GROWTH

THEN AND NOW—A SUMMARY

A COMPARISON OF THE FINDINGS OF THE CARD STUDY IN 1971 WITH A CURRENT EVALUATION OF PROBLEM AREAS REVEALS THE FOLLOWING POINTS:

- Safety, airside congestion and high user costs remain unsolved problems
- Foreign competition, environmental concerns, and energy inefficient aircraft should have been foreseen as potential problem areas
- The G.A. industry cannot solve all existing problems and adequately provide for future advancements
- General Aviation needs NASA assistance to solve critical problems and to provide a technology base for future growth.

AREAS WHERE G.A. NEEDS ASSISTANCE

- BASIC AERODYNAMIC RESEARCH

- NOISE REDUCTION

- EMISSIONS

- STRUCTURAL CRASHWORTHINESS

- GUST & TURBULENCE RESEARCH

- AIRFRAME ICING

- AVIONICS

- PILOT TRAINING

GAMA 1976

AREAS WHERE GENERAL AVIATION INDUSTRY NEEDS ASSISTANCE (GAMA)

According to GAMA,⁷ emphasis in aeronautics by NASA will, of course, have a fall-out effect for G.A. This should be particularly true in the areas of noise and emissions. Areas where industry needs specific NASA R&T are the following:

BASIC AERODYNAMIC RESEARCH:

In many respects, the industry is still using data developed by the NACA a number of years ago. Fundamental design data for new technology items are needed. Design information presented in a "cookbook fashion," accumulated from NASA wind tunnels, would be very useful to the industry. Much of this information is beyond the scope of the manufacturing industry to develop.

A revitalization of NASA basic aerodynamic research would be beneficial in both safety and increased efficiency.

Increased efficiency and safety may result from research efforts in new stall/spin criteria, radio-controlled, powered-model testing techniques, flight testing of an aircraft with several tail configurations; a new family of airfoil shapes and the work that has been started in the GAW- wing series.

NOISE REDUCTION:

NASA can play a greater role, through the investigation of the causes and sources of noise and the development of exhaust system and propeller design technology, to reduce noise while maintaining aircraft efficiency.

⁷ Edward W. Stimpson, president of GAMA, Congressional Testimony, September, 1974.

AREAS WHERE G.A. NEEDS ASSISTANCE

- BASIC AERODYNAMIC RESEARCH
- NOISE REDUCTION
- EMISSIONS
- STRUCTURAL CRASHWORTHINESS
- GUST & TURBULENCE RESEARCH
- AIRFRAME ICING
- AVIONICS
- PILOT TRAINING

GAMA 1976

EMISSIONS:

NASA can assist the industry through its propulsion environmental impact minimization research and technology program which will lead to a reduction in aircraft propulsion system noise and exhaust pollution emissions, and will develop improved methods for prediction of the noise and pollution impact on the environment.

STRUCTURAL CRASHWORTHINESS:

The G.A. industry is currently cooperating with NASA in its crashworthiness programs. The current cooperative tests, involving controlled impacts of flood damaged, but otherwise new and modern, G.A. airplanes at NASA Langley, will provide valuable information on seat design, occupant restraints and structural protection that would not otherwise be available. One manufacturer's misfortune in losing new airplanes in a flood is being turned into some benefit for the industry through these controlled impact programs.

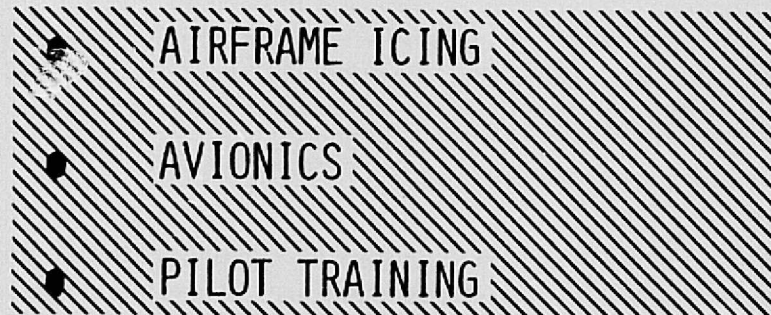
One side benefit may be more informed positioning of emergency locator beacons. The present practice is to locate and arm beacons in a manner calculated to cause them to operate in an accident but not inadvertently. Unfortunately, calculations may not cover all situations.

GUST AND TURBULENCE RESEARCH:

One major turbulence problem is wake vortices generated by very heavy aircraft flying at the relatively low speeds necessary for approach and landing. The problem is handled now by using large and perhaps excessive separation between heavy jets and other aircraft. Work should continue on detection and avoidance procedures to protect those in smaller airplanes. A second problem is that of required structural strength of airplanes based on actual gust experience. NASA has gathered some 150,000 hours of experience which is now being summarized.

AREAS WHERE G.A. NEEDS ASSISTANCE

- BASIC AERODYNAMIC RESEARCH
- NOISE REDUCTION
- EMISSIONS
- STRUCTURAL CRASHWORTHINESS
- GUST & TURBULENCE RESEARCH



GAMA 1976

AIRFRAME ICING:

Many G.A. airplanes are prohibited from flying into known icing conditions because of the weight and cost of equipment necessary to remove ice, or because the manufacturer experienced difficulty in locating suitable icing conditions in which to demonstrate the icing characteristics of the airplane. More basic information relating to ice formation, prevention and removal are required. Little basic work has been done in this field in recent years.

AVIONICS:

There is no question but that the G.A. industry should and will use much of the advanced avionics developed by NASA for use in space. The role of NASA should be in technology transfer and not in attempting to create specific pieces of hardware or so-called "lost cost" variations of devices that are available commercially.

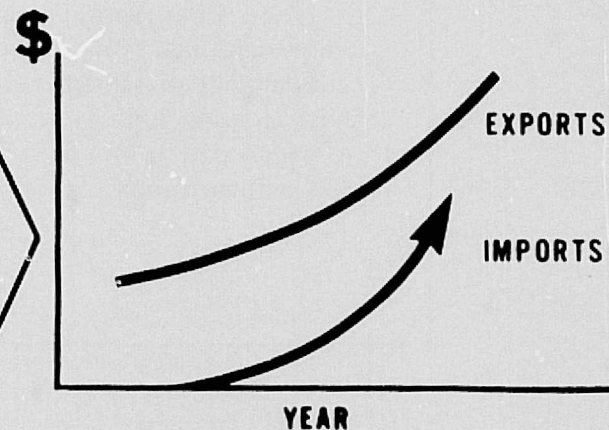
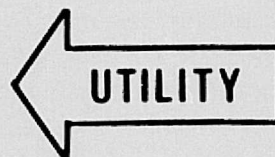
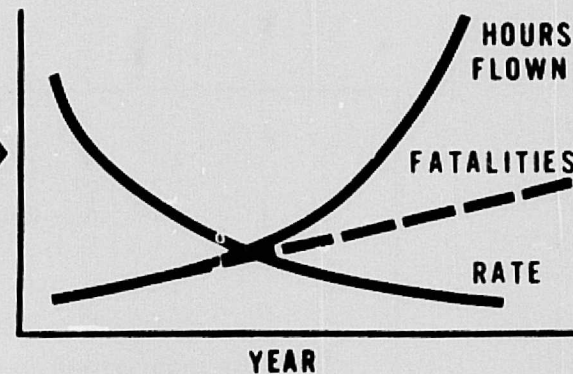
PILOT TRAINING:

Pilot error accounts for 80 percent of the G.A. accidents. NASA must develop some mechanism for maintaining pilot proficiency and training.

PROBLEMS IN GENERAL AVIATION

IMPROVEMENTS NEEDED IN

- COST
- RELIABILITY
- MAINTENANCE
- FUEL EFFICIENCY
- NOISE
- EMISSIONS



NASA HQ RA75-15525(3)
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PROBLEMS IN GENERAL AVIATION

To sustain the growth rate to which G.A. has become accustomed, and to preserve its impact on the U.S. economy, solutions for the following critical problems must be found:

SAFETY:

Despite the steady decrease in accident (and fatality) rates, an increasing number of operations maintain the gross numbers at high levels. Several measures could be taken to reduce these levels, such as:

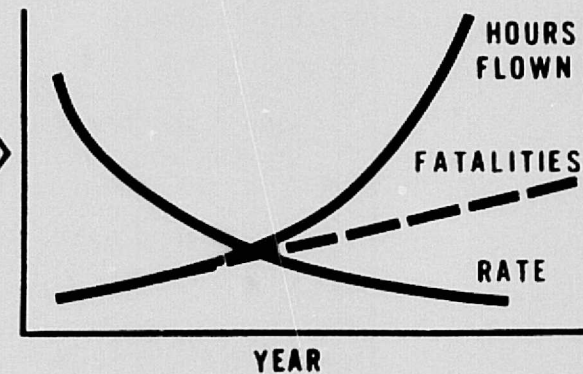
- Improved controls for identifying and correcting safety defects on light aircraft
- Improved avionics to reduce pilot workload during instrument flights
- Better prediction methods and design techniques to define the spin characteristics of future G.A. aircraft and to identify ways of coping with the spin tendencies of existing designs
- Development of design data and procedures for improved structural crashworthiness of light aircraft providing for greater protection of passengers in the event of a crash
- Research and test activities to improve runway traction, develop impact-absorbing approach light structures, heat runways, reduce bird hazards, and provide better cockpit visibility.

PROBLEMS IN GENERAL AVIATION

IMPROVEMENTS NEEDED IN

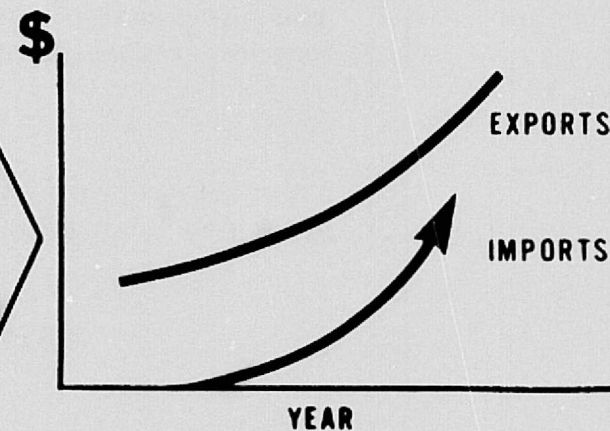
- ▶ COST
- ▶ RELIABILITY
- ▶ MAINTENANCE
- ▶ FUEL EFFICIENCY
- ▶ NOISE
- ▶ EMISSIONS

SAFETY



UTILITY

EXPORT
POSITION



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UTILITY:

Costs

- Concern over the high inflationary costs involved in incorporating any new advanced technology in operational aircraft that would effect significant fuel savings in a future fuel scare and high price environment
- Increased user charges, and cost of avionics sophistication added to aircraft already operational, substantially impact the growth of the industry.

Reliability and Maintenance

- Industry is still using data developed by the NACA a number of years ago. Basic knowledge is needed in such areas as controllability, handling qualities, approach path control, stalls and spins.

Fuel Efficiency

- Very little has been done in the past decade in the field of engine cooling, internal fuel distribution and the optimization of burning to lead to an increase in fuel efficiency.

Noise

- Public concern about aircraft noise has resulted in many proposals being submitted to FAA requesting that restrictions be placed on the use of airspace, the setting of new airports, and calling for airport curfews.

Emissions

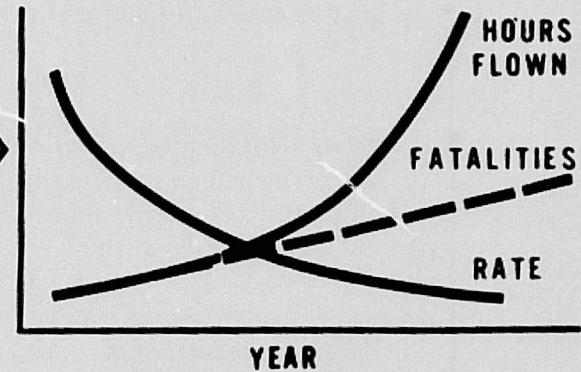
- Current regulations prescribing emission standards for the control of air pollution from aircraft and aircraft engines which must be met by turbine-powered engines by January 1, 1979, and by piston engines by December 31, 1979, present the industry with a serious problem.

PROBLEMS IN GENERAL AVIATION

IMPROVEMENTS NEEDED IN

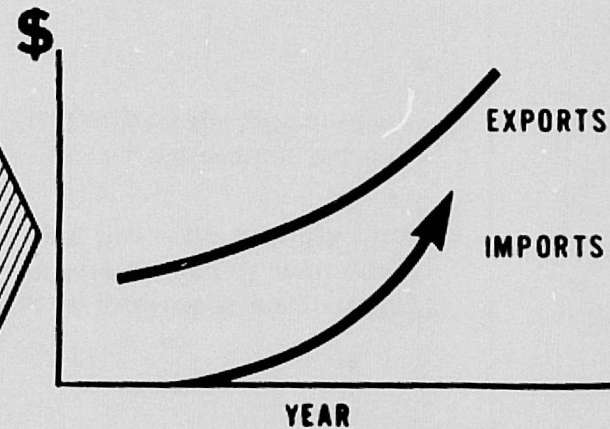
- ▶ COST
- ▶ RELIABILITY
- ▶ MAINTENANCE
- ▶ FUEL EFFICIENCY
- ▶ NOISE
- ▶ EMISSIONS

SAFETY



UTILITY

EXPORT
POSITION



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EXPORT POSITION:

Foreign Competition

- General aviation manufacturers have built 90 percent of the free world fleet with 1975 production at 97-98 percent of the market. However, foreign governments are taking definite action to reverse their adverse balance of trade posture. Since a one percent change in GNP results in a 1.6 percent change in the G.A. fleet size and a 2.05 percent change in operations, the industry must face the following challenges:
 - Foreign industries subsidized by their governments can offer aircraft at lower unit costs, using price as a bargaining tool
 - Demand of foreign governments to buy European aircraft to promote balance of trade
 - To protect their foreign market, U.S. manufacturers are entering into joint ventures with foreign firms. This is raising concern by some, of technology transfer, and a loss of much of the manufacturing work to foreign partners.

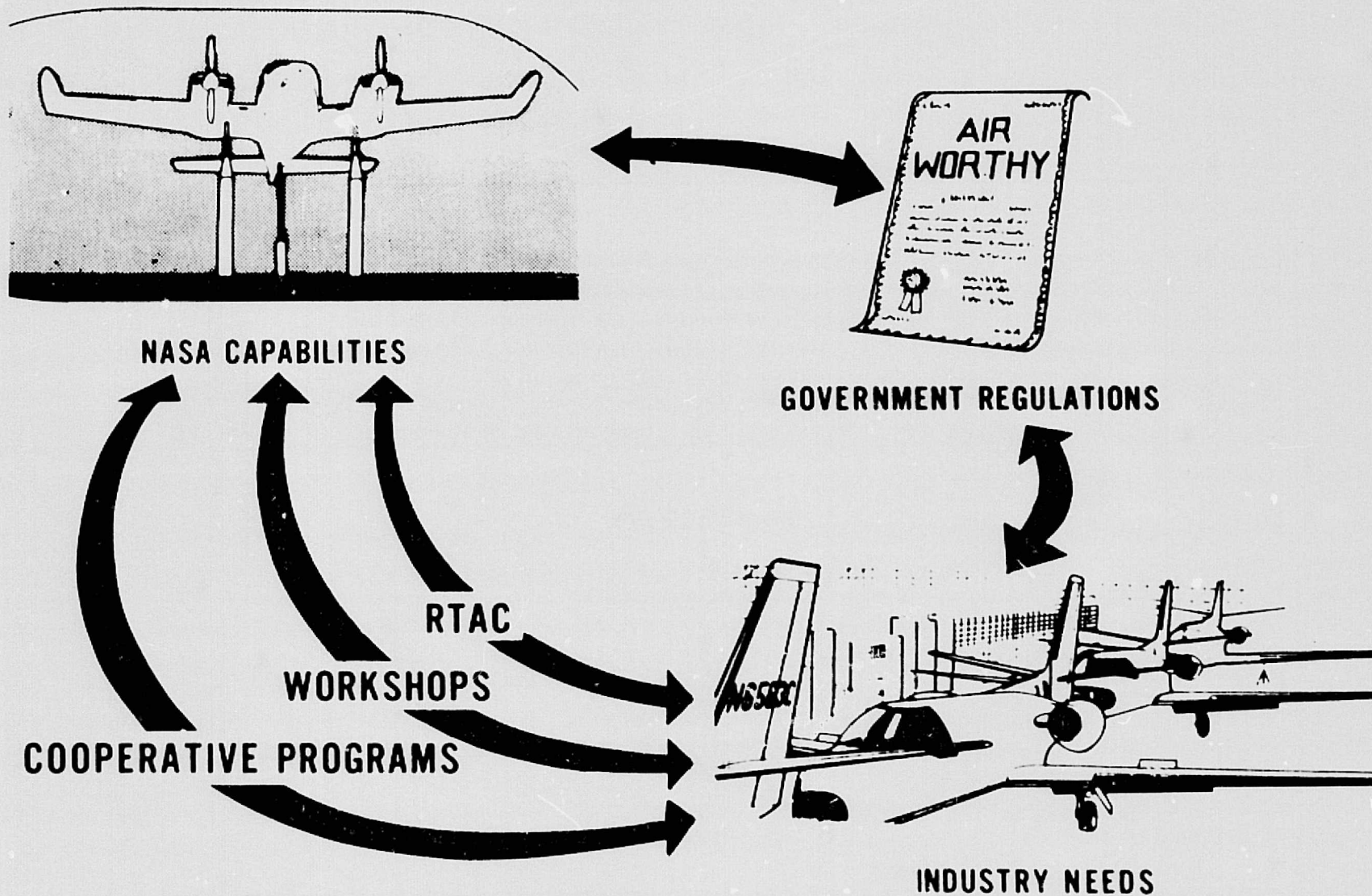
NASA RESPONSE

- BETTER COMMUNICATION WITH G.A. INDUSTRY
- SUSTAINED NASA RESEARCH AND TECHNOLOGY PROGRAM FOR G.A.

NASA RESPONSE

In response to these problem areas, the objective of the NASA program in G.A. is to provide a modern technology base that will permit the design of future light aircraft that are safer, more productive and clearly superior to emerging foreign competition. In order that research efforts toward this objective yield maximum benefit, the capabilities of NASA must be carefully matched against the specific technology needs of the industry/user community, taking into consideration their unique capabilities and limitations.

CHANNELS FOR COMMUNICATION



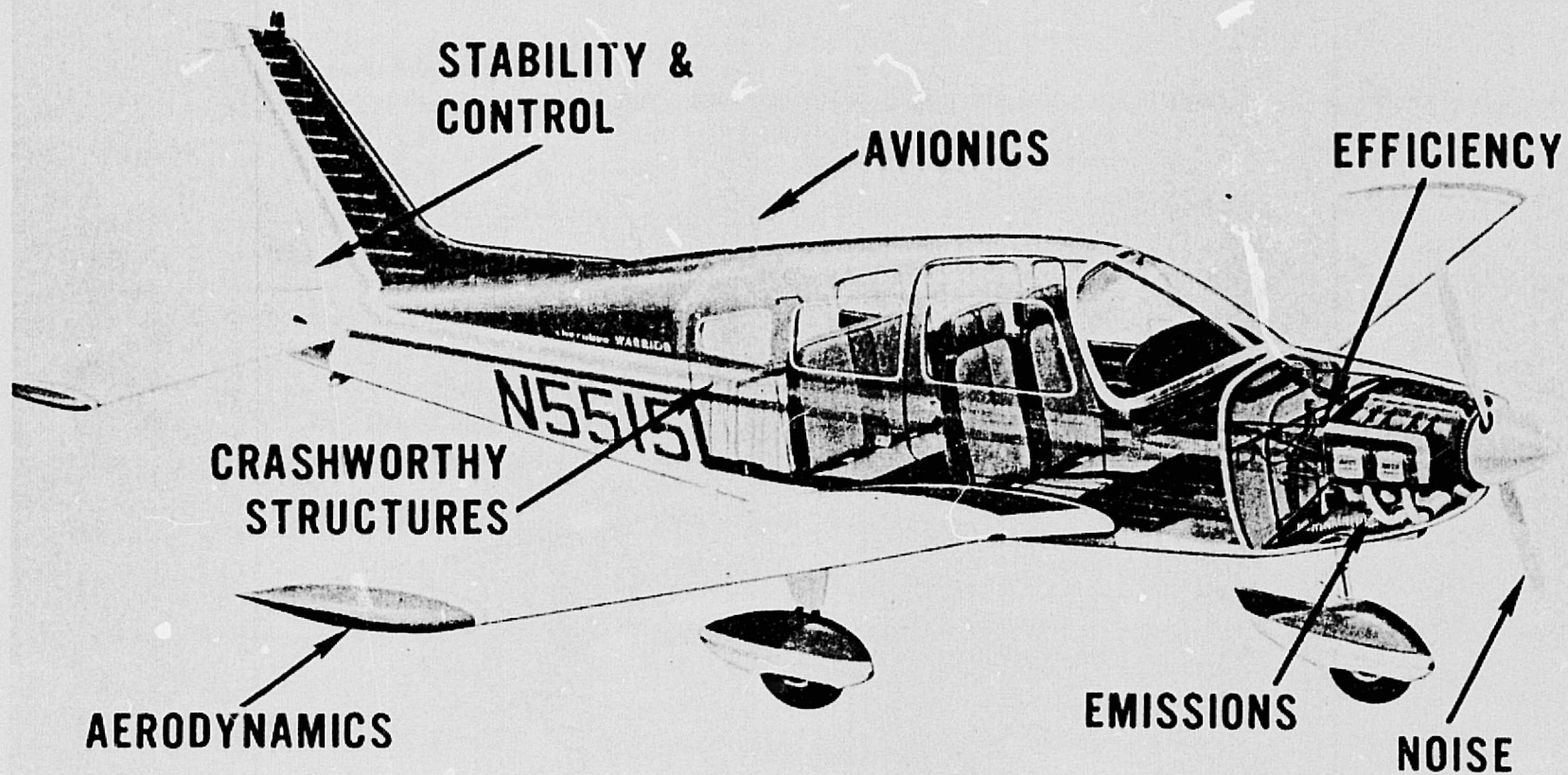
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CHANNELS FOR COMMUNICATION

A key to providing a match of NASA technical capabilities with G.A. industry needs is the development of more effective communications between them. The Research and Technology Advisory Council's Panel on General Aviation Technology Review of NASA's G.A. program, resulted in a number of cogent recommendations that will ensure even greater relevance to the needs of industry. To provide an additional forum for discussion of these industry needs, NASA also initiated a series of "technical direction" workshops. These one- to three-day meetings between key industry experts and their NASA counterparts focus on specific technology problem areas. The workshops are timed as nearly as possible to coincide with the program planning and definition phases of specific NASA programs. Contacts established through these meetings should result in better communication and facilitate the more rapid transfer of research results to the users.

In addition to establishing channels for improved communication, joint cost-shared activities between NASA and the industry have been undertaken in several critical areas. Individual companies or the industry as a whole, as represented by the General Aviation Manufacturers Association (GAMA), are actively working with NASA in the crashworthiness program, stall/spin research, emissions and noise reduction.

NASA RESEARCH PROGRAM IN GENERAL AVIATION



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NASA RESEARCH PROGRAM IN GENERAL AVIATION

The research and technology development program that NASA is directing toward G.A. has grown over the past few years, reaching approximately \$5 million in FY 1975. In FY 1976, approximately \$6.2 million was allocated to this program. Note that the resources and programs described here are those directed at unique G.A. technology needs. It is estimated that between \$10 and \$15 million of the R&T base program will directly relate to G.A. needs. Specific technology developments are under way and planned to continue during FY 1978 in aerodynamics, avionics, propulsion, structures and materials, and operations. System study efforts will continue as a means of defining future needs.

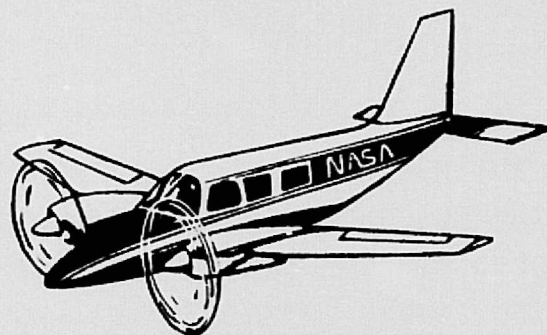
These efforts are being carried out at the NASA Research Centers and under contract to industry. In addition to theoretical studies and analyses, the various program elements frequently involve the use of hardware for proof-of-concept testing and the general testing of empirical data over a wide range of conditions. Criteria for design and acquisition of the test articles are dictated by the research task to be performed. Consequently, rarely, if ever, is the test hardware capable of direct translation to a commercial product because of the compromises made necessary to yield generalized design information. In total, the individual program elements comprise an effort that will provide the technology necessary to meet the stated program objective.

A more detailed treatment of NASA R&T in G.A. can be found in the enclosed publication, "General Aviation Technology Program," March 1976, in Appendix A.

RELEASE NO: 76-51

MARCH 1976

General Aviation Technology Program



APPENDIX A

NASA

National Aeronautics and
Space Administration

GENERAL AVIATION

RESEARCH AND TECHNOLOGY PROGRAM

THE IMPORTANCE OF THE GENERAL AVIATION SEGMENT OF THE U.S. CIVIL AIR TRANSPORTATION SYSTEM CONTINUES TO GROW. EACH YEAR VIRTUALLY EVERY INDICATOR OF EFFECTIVENESS INCREASES. THE CONTINUING GROWTH IN HOURS FLOWN, PEOPLE, CARGO AND MAIL CARRIED AND ACRES OF CROPS SERVICED ARE REFLECTED IN THE INCREASED PRODUCTION AND SALE OF NEW AIRPLANES AND EQUIPMENT AROUND THE WORLD. THIS YEAR, FOR THE FIRST TIME, INDUSTRY STATISTICS SHOW \$1 BILLION IN SALES.

THESE INCREASES OVER THE PAST FEW YEARS HAVE BEEN PARALLELED BY THE GROWING EMPHASIS PLACED ON GENERAL AVIATION BY NASA. IN TERMS OF RESOURCES, THE NASA GENERAL AVIATION PROGRAM HAS GROWN FROM \$2.7 MILLION IN FY 1973 TO \$8.5 MILLION IN FY 1977. FROM A SMALL NUMBER OF INDIVIDUAL PROJECTS, THE NASA PROGRAM HAS PROGRESSED TO A COORDINATED EFFORT ADDRESSING NEARLY ALL OF THE MAJOR TECHNOLOGICAL PROBLEMS IN LIGHT AVIATION.

INDUSTRY PARTICIPATION AND SUPPORT OF THE NASA EFFORT HAS GROWN EVEN FASTER THAN THE PROGRAM ITSELF. THROUGH THE RESEARCH AND TECHNOLOGY ADVISORY COUNCIL'S PANEL ON GENERAL AVIATION TECHNOLOGY, THE TECHNICAL WORKSHOP SERIES AND JOINT RESEARCH EFFORTS, THE SPECIFIC NEEDS OF GENERAL AVIATION ARE BEING REFLECTED IN NASA RESEARCH PROGRAMS.

IN SEVERAL AREAS, RESULTS FROM NASA RESEARCH EFFORTS ARE BEING REFINED IN PRODUCT DEVELOPMENT PROGRAMS BY THE INDUSTRY. NOTABLE AMONG THESE ARE AERODYNAMIC IMPROVEMENTS IN THE FORM OF NEW AIRFOILS. FLIGHT CONTROL AND HIGH LIFT DEVICES AND AIRFOIL MODIFICATIONS ARE CURRENTLY IN PROTOTYPE FLIGHT TESTING. TECHNIQUES DEVELOPED BY NASA FOR SPIN TESTING HAVE BEEN WIDELY ACCEPTED AND USED BY THE INDUSTRY OVER THE PAST TWO YEARS.

TO INSURE AN ADEQUATE BASE OF NEW TECHNOLOGY TO SUPPORT THE CONTINUED GROWTH IN THE UTILITY OF THE LIGHT AIRPLANE, NASA PLANS TO CARRY OUT GENERAL AVIATION-ORIENTED EFFORTS IN EACH OF THE AERONAUTICAL DISCIPLINES. THE OBJECTIVES OF THE NASA PROGRAM ARE TO PROVIDE NEW TECHNOLOGY ACROSS THE BOARD FOR IMPROVEMENTS IN SAFETY, EFFICIENCY AND FOR REDUCTION OF THE ENVIRONMENTAL IMPACT OF GENERAL AVIATION.

AS THE USE OF SMALL AIRCRAFT EXPANDS, PARTICULARLY AS A MEANS OF TRANSPORTATION, SAFETY BECOMES OF INCREASED CONCERN. ALTHOUGH THE RATE OF BOTH ACCIDENTS AND FATALITIES CONTINUES TO DECLINE, INCREASED OPERATIONS RESULT IN A SLIGHTLY INCREASING NUMBER OF FATALITIES EACH YEAR.

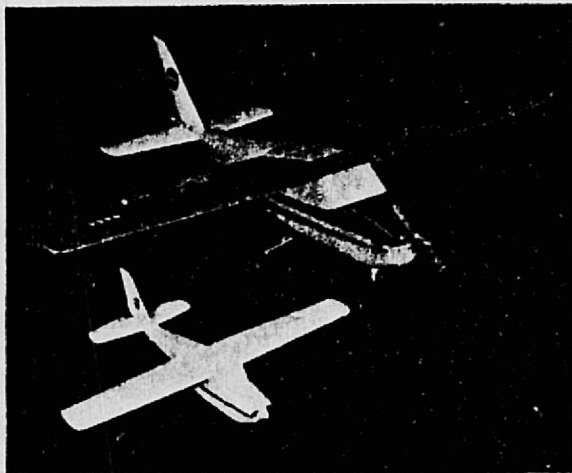
STALL/SPIN RESEARCH

WHILE THERE ARE MANY FACTORS RESPONSIBLE FOR ACCIDENTS, THE LARGEST SINGLE FACTOR IN GENERAL AVIATION FATAL ACCIDENTS IS THE STALL/SPIN. THE RESEARCH OBJECTIVE OF THE NASA GENERAL AVIATION STALL/SPIN RESEARCH EFFORT IS TO PROVIDE DESIGN DATA AND CRITERIA FOR EFFICIENT LIGHT AIRCRAFT THAT WILL NOT STALL OR SPIN UNINTENTIONALLY. AS REPRESENTED IN FIGURE 1, PARAMETRIC DATA ON SPIN ENTRY AND RECOVERY ARE BEING GENERATED IN A LONG RANGE PROGRAM THAT WILL ULTIMATELY PROVIDE A BASIS FOR FUTURE AIRCRAFT DESIGN. THE MAJORITY OF THE DATA IS ACQUIRED USING THE SPIN TUNNEL AND RADIO CONTROLLED MODELS. SUFFICIENT FULL-SPIN TESTING WILL BE ACCOMPLISHED TO VERIFY ACCURACY OF THE MODEL DATA. TO DATE, MORE THAN 2,500 TEST RUNS IN THE SPIN TUNNEL AND 300 FREE-FLIGHT RADIO CONTROLLED MODEL FLIGHTS HAVE BEEN COMPLETED. THIS REPRESENTS ABOUT 35 PERCENT OF THE PLANNED PROGRAM. BECAUSE OF DELAYS IN FABRICATION OF THE MODIFIED TAIL ASSEMBLIES, THE FIRST SERIES OF FULL-SCALE SPIN TESTS WILL BEGIN IN THE SPRING OF 1976.

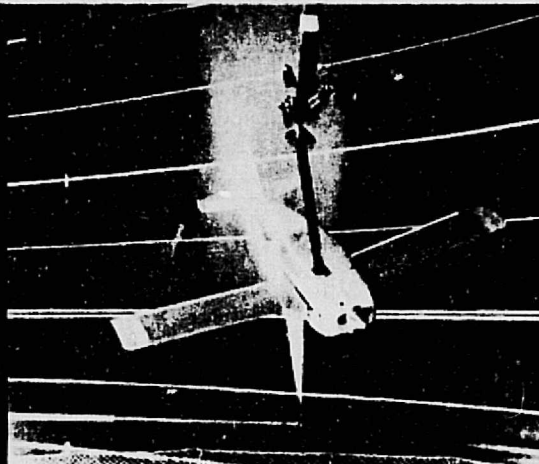
INTERIM RESULTS IN THE FORM OF TECHNICAL REPORTS SUMMARIZING AVAILABLE DATA AND PROVIDING SPIN RECOVERY PARACHUTE DESIGN PARAMETERS HAVE BEEN DISSEMINATED. THE NOW WIDELY USED RADIO CONTROLLED MODEL TEST TECHNIQUE WAS AN EARLY DEVELOPMENT FROM THIS EFFORT.

A SEPARATE EFFORT, BUT AN INTEGRAL PART OF THE STALL/SPIN SOLUTION, IS CONCENTRATING ON PREDICTING AND MODIFYING THE STALL CHARACTERISTICS OF THE WING THROUGH AERODYNAMIC CHANGES. RESULTS FROM THIS EFFORT HOLD PROMISE FOR DESIGNING INTO A WING THE SPECIFIC STALL BEHAVIOR REQUIRED WITHOUT LOSS IN EFFICIENCY OR PERFORMANCE. DEMONSTRATION OF THE ANALYTICALLY DERIVED TECHNIQUE WILL BE CARRIED OUT THROUGH WIND TUNNEL TESTING AND FLIGHT VALIDATION.

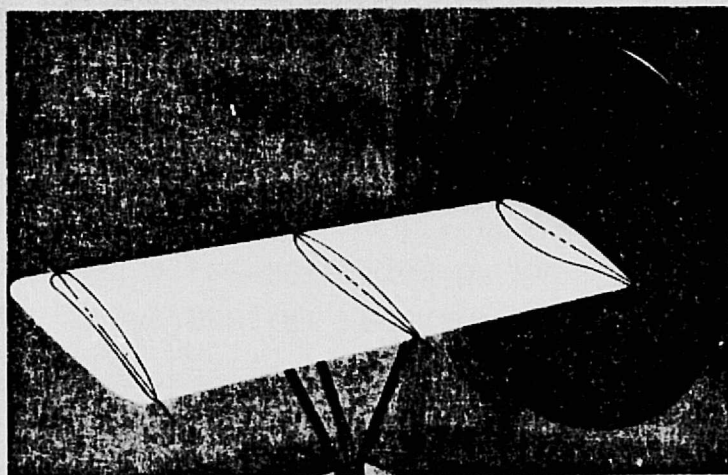
NASA STALL/SPIN RESEARCH



MODELS FOR DEVELOPMENT OF DATA BASE



FULL SCALE AIRCRAFT FOR VALIDATION



AERODYNAMIC DESIGN FOR OPTIMUM STALL RESISTANCE

NASA HEADQUARTERS
1974

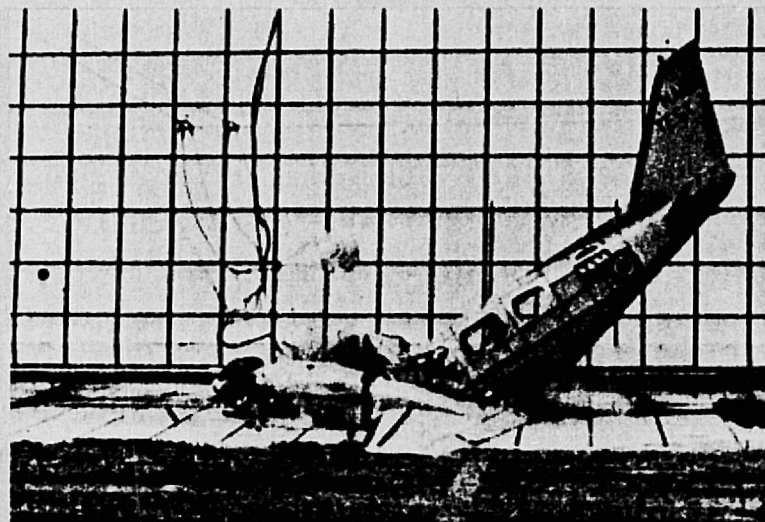
Figure 1

CRASHWORTHINESS

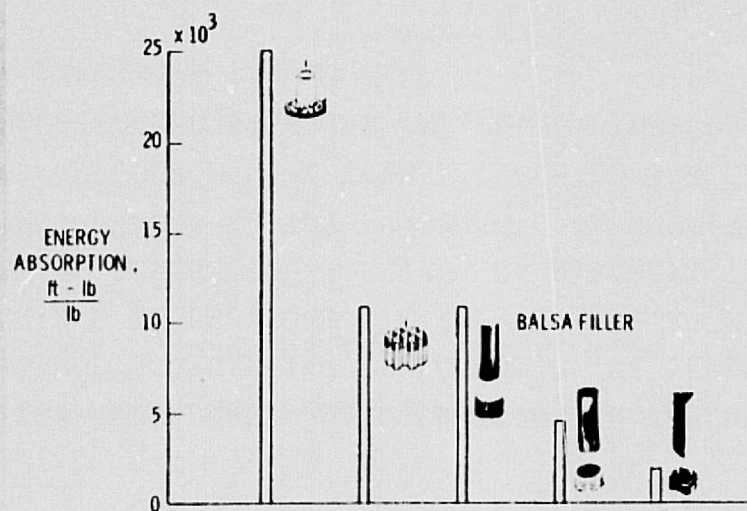
A SECOND MAJOR EFFORT ADDRESSING SAFETY IN GENERAL AVIATION IS ILLUSTRATED IN FIGURE 2. THIS PROGRAM WILL DEVELOP DESIGN DATA AND PROCEDURES FOR IMPROVED STRUCTURAL CRASHWORTHINESS. A JOINT NASA - FAA INDUSTRY PROGRAM, IS DEVELOPING STRUCTURAL DESIGN PROCEDURES TO PROVIDE FOR GREATER PROTECTION OF PASSENGERS IN THE EVENT OF A CRASH. THEORETICAL ANALYSES AND PREDICTION OF THE DYNAMIC BEHAVIOR OF THE AIRCRAFT STRUCTURE UNDER CRASH IMPACT LOADS ARE THE BASIS FOR NEW DESIGN PROCEDURES. FULL-SCALE SIMULATIONS OF AIRCRAFT CRASHES ARE BEING CARRIED OUT -- TO PROVIDE DATA FOR VALIDATION OF THEORY AND TO EVALUATE AIRFRAME COMPONENTS UNDER ACTUAL CRASH IMPACT CONDITIONS.

TO DATE, NINE FULL-SCALE TESTS HAVE BEEN CONDUCTED, INCLUDING ONE CH-47 HELICOPTER. SIX ADDITIONAL TESTS WILL BE CARRIED OUT DURING THE NEXT YEAR. PRELIMINARY DATA THUS FAR INDICATE THAT THE GREATEST LOADS ARE VERTICAL AND ARE ENCOUNTERED DURING THE SECONDARY IMPACT. THE IMPLICATION IS THAT ENERGY ABSORBING SEATS MAY PROVIDE GREATER BENEFIT THAN ANTICIPATED. A NASA/INDUSTRY WORKSHOP IS SCHEDULED FOR THE SPRING OF 1976 TO SUMMARIZE THE RESULTS TO DATE.

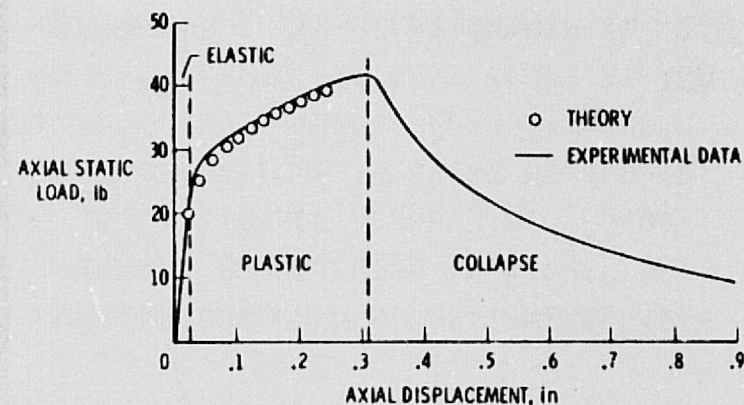
NASA RESEARCH FOR IMPROVED CRASH WORTHINESS



FULL SCALE TESTS



COMPONENT TESTS



ANALYTICAL PREDICTION

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Figure 2

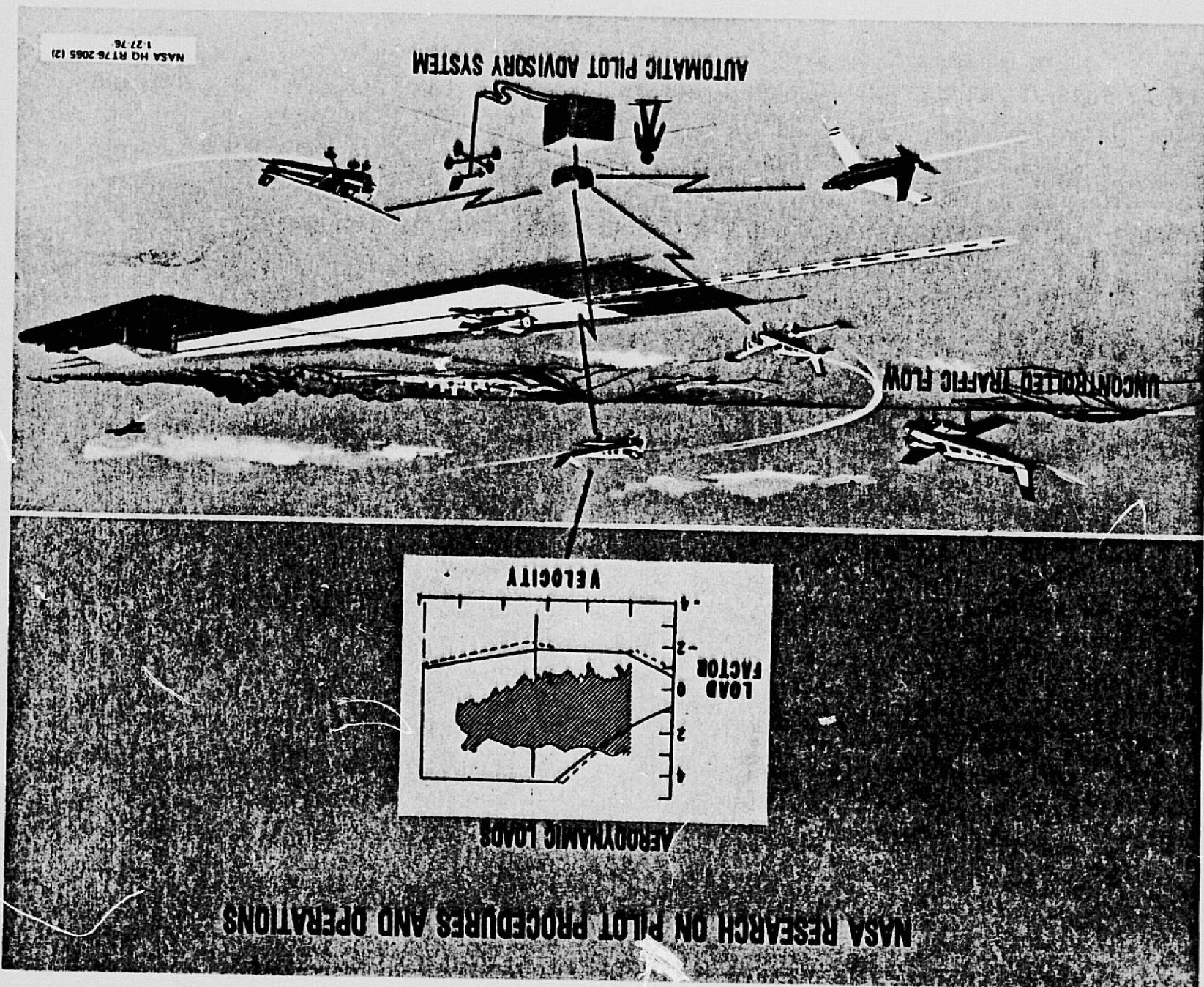
PILOT OPERATIONS

PILOT PROCEDURES AND OPERATIONS IN THE UNCONTROLLED ENVIRONMENT OF GENERAL AVIATION AIRPORTS ARE BEING EXPLORED IN THE SEVERAL PROGRAMS REPRESENTED IN FIGURE 3. AS DESCRIBED IN PREVIOUS STATEMENTS, A STATISTICAL DEFINITION OF AERODYNAMIC LOADS EXPERIENCED ACROSS THE SPECTRUM OF AIRCRAFT TYPES AND OPERATIONS IS BEING DEVELOPED. THE LATEST REPORT ON THE ANALYZED DATA WAS ISSUED IN DECEMBER 1975. APPROACH AND LANDING PROCEDURES HAVE BEEN DOCUMENTED AND REPORTED. TRAFFIC PATTERNS FLOWN AT AND NEAR UNCONTROLLED AIRPORTS ARE BEING STUDIED TO UNDERSTAND THEIR RELATIONSHIP TO MID-AIR COLLISION POTENTIAL.

AS A RESULT OF STUDIES OF TRAFFIC NEAR THE UNCONTROLLED AIRPORT, A CONCEPT HAS BEEN DEVELOPED THAT HOLDS PROMISE FOR PROVIDING A REASONABLE INCREMENT OF PROTECTION AND ADVISORY SERVICE TO AIRCRAFT OPERATING FROM THESE FIELDS. BASED ON THE COMBINATION OF EXISTING COMMERCIAL RADAR, MINI-COMPUTERS AND VOICE SYNTHESIZERS, IT APPEARS THAT AN AUTOMATED PILOT WARNING AND ADVISORY SYSTEM CAN BE DEVELOPED.

SUCH A SYSTEM WOULD DETECT AND ANNOUNCE THE LOCATION AND DIRECTION OF ALL TRAFFIC WITHIN A LIMITED AREA SURROUNDING THE AIRPORT. POTENTIAL COLLISION THREATS WOULD BE IDENTIFIED AND A WARNING AUTOMATICALLY BROADCAST. AUTOMATIC SENSING AND ANNOUNCEMENT OF AIRPORT CONDITIONS SUCH AS WIND, PRESSURE AND TEMPERATURE COULD BE INCLUDED. COMPONENTS ARE CURRENTLY BEING EVALUATED, WITH A BREADBOARD DEMONSTRATION PLANNED BY THE END OF THIS YEAR. ESTIMATES ARE THAT WITH A REASONABLE PRODUCTION QUANTITY, THE UNIT PRICE WOULD BE ABOUT THE SAME AS THE COST OF A SINGLE ENGINE TRAINER AIRPLANE.

Figure 3



ENTRY INTO IFR CONDITIONS FOR AN INEXPERIENCED PILOT CAN CAUSE PROBLEMS RANGING FROM LOSS OF GEOGRAPHIC ORIENTATION TO FULL LOSS OF CONTROL. EFFORTS TOWARD USE OF FLUIDICS FOR FLIGHT CONTROL AND SENSORS ARE SHOWING PROMISE FOR EXTREMELY LOW COST AND VERY HIGH RELIABILITY. TWO WING LEVELER AUTOPILOTS HAVE BEEN DEMONSTRATED IN THE PAST YEAR. THIS WORK IS BEING EXTENDED TO SHOW FEASIBILITY OF A THREE-AXIS AUTO-PILOT. EMPHASIS THIS YEAR WILL BE ON DEMONSTRATION OF ALL FLUIDIC STALL ONSET SENSORS.

FLIGHT EFFICIENCY

OVERALL EFFICIENCY OF THE LIGHT AIRCRAFT IN TERMS OF PAYLOAD VERSUS GROSS WEIGHT OR SPEED VERSUS HORSEPOWER HAS NOT CHANGED SIGNIFICANTLY FOR SEVERAL DECADES. MODERN AERODYNAMIC, PROPULSION AND SYSTEMS TECHNOLOGY, IF IT CAN BE DEVELOPED TO MEET THE ECONOMIC LEVELS OF GENERAL AVIATION, CAN PROVIDE SIGNIFICANT ADVANCES IN AIRPLANE AND SYSTEMS EFFICIENCY.

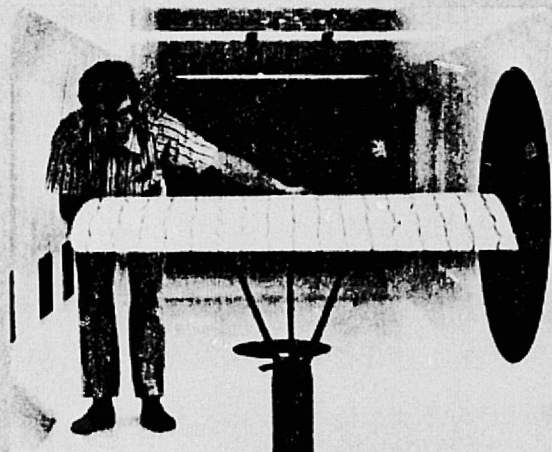
PREVIOUS NASA EMPHASIS HAS CONCENTRATED ON LOW SPEED AERODYNAMICS, PARTICULARLY WITH RESPECT TO AIRFOIL DEVELOPMENT. AS SHOWN IN FIGURE 4, THE INITIAL RESULT OF THIS EFFORT WAS THE GAW-1 AIRFOIL. SEVENTEEN PER CENT THICK AND OPTIMIZED FOR GENERAL AVIATION APPLICATION, IT EXHIBITS SIGNIFICANT IMPROVEMENTS OVER PREVIOUSLY AVAILABLE AIRFOILS. WIND TUNNEL TESTS OF THE GAW-2 HAVE NOW BEEN COMPLETED AND REPORTED. THIS 13 PER CENT THICK AIRFOIL SHOWS MARKED IMPROVEMENTS IN BOTH LIFT AND DRAG CAPABILITY OVER ITS PREDECESSOR. DESIGN DATA ON FLAPS AND CONTROL DEVICES FOR THESE AIRFOILS ARE ALSO BEING DEVELOPED. EXPANSION OF THIS SERIES OF AIRFOILS WILL CONTINUE, EXPLORING BOTH THICKER AND THINNER SECTIONS AND A RANGE OF DESIGN LIFT COEFFICIENTS.

WIND TUNNEL-DERIVED AIRFOILS ARE THE BASIS FOR VIRTUALLY ALL EXISTING LIGHT AIRCRAFT DESIGNS. TRADITIONALLY AN AIRFOIL IS CHOSEN FROM "HANDBOOK" OR WIND TUNNEL DATA PERMITTING THE DESIGNER TO SELECT THE AVAILABLE AIRFOIL DATA THAT COMES NEAREST HIS NEEDS. MODERN COMPUTATIONAL AERODYNAMICS HAVE NOW REACHED A LEVEL OF PRECISION IN THE LOW SPEED RANGE THAT PERMITS AN AIRFOIL TO BE OPTIMIZED FOR EACH SPECIFIC APPLICATION.

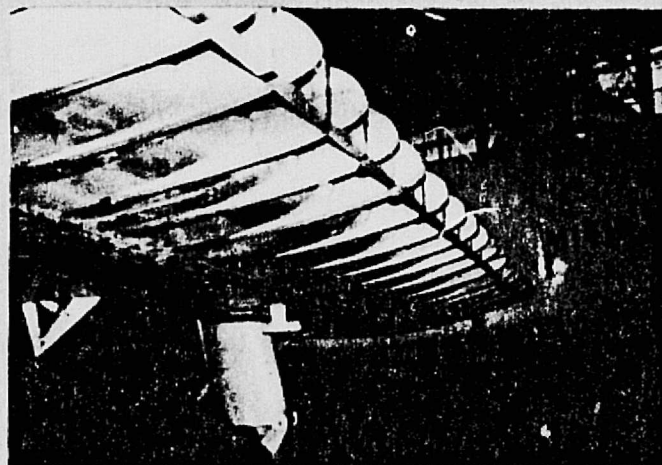
NASA AIRFOIL DEVELOPMENT



COMPUTATION



WIND TUNNELS



FLIGHT VALIDATION

NASA HQ RT76-2066 (3)
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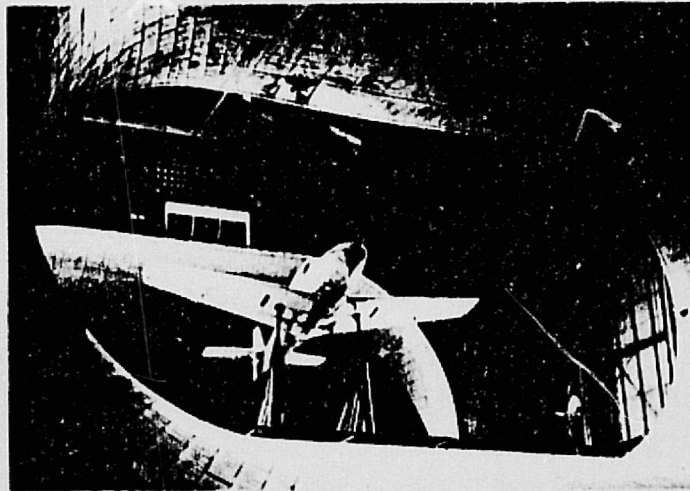
NASA HAS USED THESE TECHNIQUES EXTENSIVELY IN SUPPORT OF IN-HOUSE PROGRAMS, AS DO THE LARGE TRANSPORT MANUFACTURERS. TO PROVIDE THESE TOOLS IN A FORM ACCESSIBLE TO THE ENTIRE GENERAL AVIATION COMMUNITY, NASA IS ESTABLISHING AN AIRFOIL DESIGN FACILITY UNDER CONTRACT. ONCE ITS CAPABILITY HAS BEEN VERIFIED, THE FACILITY WILL PROVIDE DESIGN SERVICE TO BOTH THE INDUSTRY AND NASA ON A SELF SUPPORTING BASIS.

ILLUSTRATED IN FIGURE 5, INCREASED AIRPLANE EFFICIENCY IS SYNONYMOUS WITH REDUCED AERODYNAMIC DRAG. WHILE MUCH APPLICABLE WORK WAS DONE ON DRAG REDUCTION IN THE LOW SPEED RANGE DURING WORLD WAR II, IT WAS HIGHLY CONFIGURATION SPECIFIC. MANY EVOLUTIONARY CHANGES IN LIGHT AIRCRAFT DESIGN SINCE THAT TIME HAVE RESULTED IN CONFIGURATIONS THAT ARE CONSIDERABLY DIFFERENT.

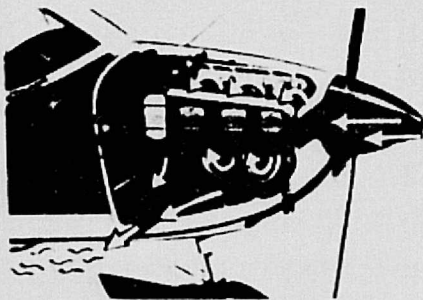
AN EXAMPLE OF THIS IS THE USE OF THE FLAT, HORIZONTALLY-OPPOSED AIR COOLED ENGINE. THE DRAG GENERATED IN COOLING THE ENGINES IS VARIOUSLY ESTIMATED TO BE BETWEEN 5 AND 20 PER CENT OF THE TOTAL CRUISE DRAG OF THE AIRPLANE. CURRENT PRACTICE IN THE DESIGN OF COWLINGS AND INTERNAL FLOW IS FOR THE MOST PART A CUT-AND-TRY PROCEDURE, SINCE NO DESIGN DATA BASE EXISTS. TWO UNIVERSITIES, WORKING CLOSELY WITH SEVERAL AIRFRAME MANUFACTURERS UNDER NASA SPONSORSHIP, ARE CONDUCTING RESEARCH INTO THE CRITICAL AREAS OF ENGINE COOLING DRAG. STUDIES OF ENGINE COOLING FIN DESIGN, INTERNAL FLOW OPTIMIZATION AND TESTING TECHNIQUES ARE BEING UNDERTAKEN. THE RESULT OF THIS CONTINUING EFFORT WILL BE A DESIGN PROCEDURE WITH SUPPORTING DATA AND TEST PROCEDURES THAT WILL MINIMIZE LOSSES IN EFFICIENCY THROUGH EXCESSIVE ENGINE COOLING DRAG.

THE TOTAL DRAG OF AN AIRPLANE IS A SUMMATION OF A NUMBER OF IDENTIFIABLE COMPONENTS. WHILE MANY OF THESE CAN BE STUDIED INDEPENDENTLY, THE DRAG RESULTING FROM INTERFERENCE

IMPROVED EFFICIENCY THROUGH DRAG REDUCTION



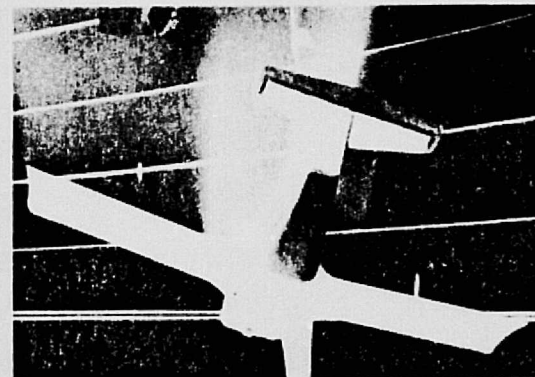
FULL CONFIGURATION DRAG CLEAN UP



ENGINE COOLING



SKIN FRICTION



INTERFERENCE

BETWEEN THE FLOW FIELDS OF THE VARIOUS COMPONENTS REQUIRES A COMPLETE AIRPLANE FOR STUDY. AN EFFORT AT THE LANGLEY RESEARCH CENTER WILL PROVIDE A MODERN SET OF DESIGN DATA FOR DRAG REDUCTION FOR CURRENT AND FUTURE LIGHT AIRCRAFT CONFIGURATIONS.

SMALL-SCALE WIND TUNNELS, FULL-SCALE WIND TUNNELS AND INSTRUMENTED FLIGHT TESTS WILL PROVIDE DATA FOR REDUCING TOTAL AIRPLANE DRAG. SCHEDULED TO START IN FY 1977 THIS EFFORT WILL CAREFULLY REVIEW PREVIOUS TECHNIQUES FOR DRAG REDUCTION AS APPLIED TO CURRENT CONFIGURATIONS AND SPEEDS. WHERE EXISTING CONCEPTS OR DATA DO NOT APPLY, NEW PROCEDURES WILL BE DEVELOPED.

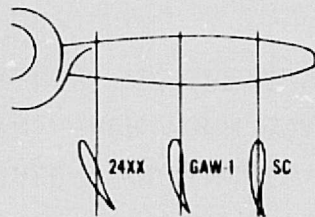
PROPULSION RESEARCH

IN DIRECT OPPOSITION TO DRAG IS THE THRUST PROVIDED BY THE PROPULSION SYSTEM. HEAVILY ORIENTED TOWARD REDUCTION OF ENVIRONMENTAL IMPACT, AS SHOWN IN FIGURE 6, SEVERAL SPECIFIC PROPULSION EFFORTS ARE ALSO DIRECTED TOWARD IMPROVED EFFICIENCY.

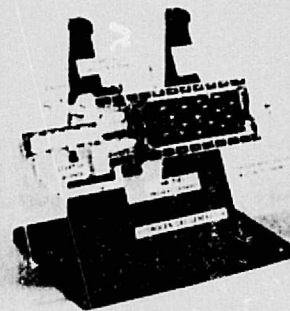
THE FIRST OF THESE EFFORTS IS ADDRESSING PROPELLER EFFICIENCY. THIS YEAR NASA WILL CONDUCT FULL-SCALE WIND TUNNEL TESTS ON THE DUCTED FAN. THE DUCTED FAN HAS SOME PROMISE OF ADVANTAGES IN LOWER FORM DRAG AND REDUCED NOISE. STUDIES OF FREE PROPELLERS HAVE INCLUDED MEASUREMENT OF THE FLUCTUATING LOADS EXPERIENCED BY PROPELLERS UNDER ACTUAL FLIGHT CONDITIONS.

THIS SPRING, FLIGHT EVALUATIONS OF A SUPERCRITICAL PROPELLER WILL BE CARRIED OUT ON THE ADVANCED TECHNOLOGY LIGHT TWIN (ATLIT). LATER, CONSIDERATION WILL BE GIVEN TO STUDYING THE USE OF COMPUTERIZED AIRFOIL OPTIMIZATION TECHNIQUES IN THE DESIGN OF PROPELLERS. COUPLED WITH POTENTIAL WEIGHT SAVINGS POSSIBLE THROUGH COMPOSITE MATERIALS,

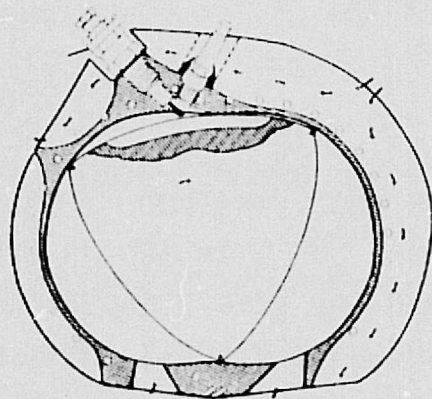
RESEARCH TO IMPROVE PROPULSION EFFICIENCY



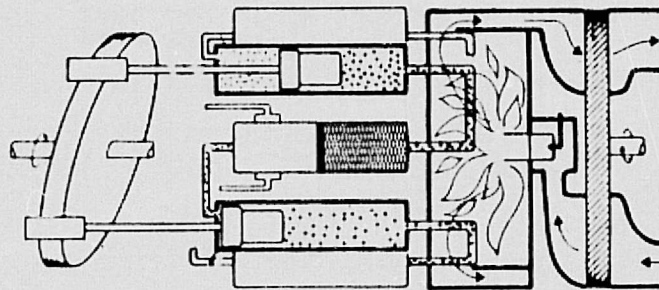
OPTIMIZED PROPELLERS



**ON BOARD HYDROGEN GENERATOR FOR
20%+ FUEL SAVINGS**

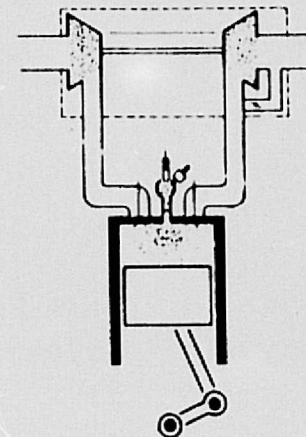


ROTARY



STIRLING

ALTERNATE ENGINE CONCEPTS



DIESEL CONVERSION

NASA HQ RT 76-2090 (3)
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SIGNIFICANT GAINS IN THRUST EFFICIENCY MAY BE POSSIBLE.

DURING THE PAST YEAR CONSIDERABLE PROGRESS HAS BEEN MADE IN APPLICATION OF THE HYDROGEN ENRICHMENT CONCEPT TO AIRCRAFT ENGINES. A TEAM CONSISTING OF THE JET PROPULSION LABORATORY, BEECH AIRCRAFT COMPANY AND AVCO-LYCOMING ARE CARRYING OUT THE DEVELOPMENT OF A SYSTEM FOR PROOF-OF-CONCEPT TESTING.

SYSTEM DESIGN STUDIES COMPLETED THIS PAST SUMMER PREDICT A 24 PER CENT REDUCTION IN FUEL USED DURING CRUISE FLIGHT. A COMPLETE FLIGHT RATED SYSTEM IS BEING FABRICATED FOR LABORATORY AND SIMULATED ALTITUDE TESTING. THE ACTUAL FLIGHT DEMONSTRATION IS SCHEDULED FOR COMPLETION EARLY IN 1977.

EXISTING RECIPROCATING ENGINES ARE EFFICIENT AND RELIABLE -- A POSITION ACHIEVED THROUGH CONTINUOUS REFINEMENT OVER MANY YEARS. OPPORTUNITIES FOR SIGNIFICANT IMPROVEMENTS IN THE BASIC ENGINE OR CYCLE EFFICIENCY ARE NOT READILY APPARENT. THE LEWIS RESEARCH CENTER HAS UNDERTAKEN A LONG-RANGE STUDY OF ALTERNATIVE ENGINE CONCEPTS THAT MAY LEND THEMSELVES TO FUTURE LIGHT AIRCRAFT PROPULSION. SEVERAL CANDIDATES HAVE BEEN IDENTIFIED FOR EXPLORATION DURING THE NEXT SEVERAL YEARS. THE VARIOUS ROTARY CONCEPTS, PRESENT STIRLING AND DIESEL ENGINE DESIGNS, ARE, IN GENERAL, NOT PRACTICAL FOR AIRCRAFT USE. THROUGH MODIFICATION, HOWEVER, THEY MAY BECOME VIABLE CANDIDATES. FIRST AREA OF EXPLORATION UNDER THIS PROGRAM IS THE CONVERSION OF AN EXISTING AIRCRAFT ENGINE TO A LOW COMPRESSION DIESEL CYCLE. ADDITIONAL CONTROLS AND PREHEATING OF THE INDUCTION AIR MAY BE REQUIRED, BUT POTENTIAL IMPROVEMENTS IN EFFICIENCY AND PERFORMANCE MAY OFFSET THE ADDED COMPLICATIONS.

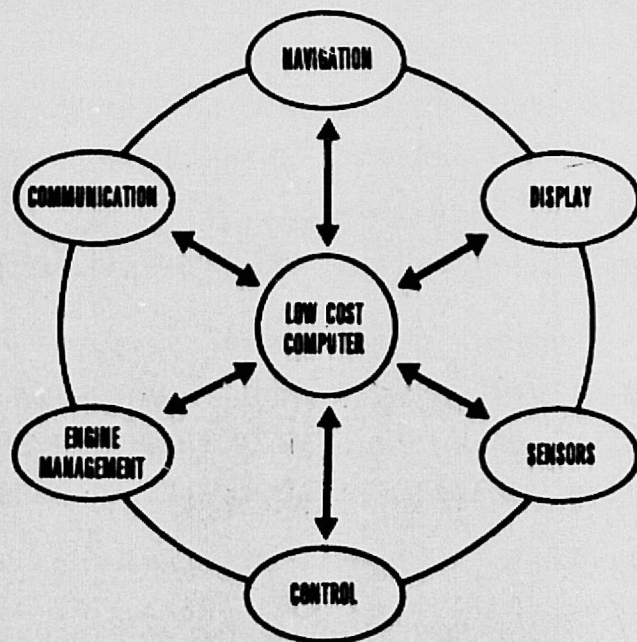
AVIONIC RESEARCH

AN EFFICIENT AIRPLANE IS NOT NECESSARILY A PRODUCTIVE MACHINE. TO ACCOMPLISH ITS PRIMARY ROLE OF TRANSPORTING PEOPLE AND GOODS, A LIGHT AIRPLANE MUST ALSO FUNCTION WITHIN THE AIRSPACE SYSTEM. REQUIREMENTS FOR ENTRY AND OPERATION WITHIN THIS SYSTEM ARE CONTINUALLY INCREASING BOTH IN TERMS OF PILOTING TASK AND AVIONIC EQUIPMENT. AS ILLUSTRATED IN FIGURE 7, NASA HAS LONG-RANGE PROGRAMS THAT ULTIMATELY WILL PROVIDE THE BASIS FOR INDUSTRY TO DESIGN AVIONIC SYSTEMS TO MORE EFFECTIVELY INTEGRATE THE LIGHT AIRPLANE WITH THE AIRSPACE SYSTEM.

POTENTIAL FOR BROADER INTEGRATION OF ALL AVIONIC FUNCTIONS INTO A SINGLE SYSTEM CONCEPT IS BEING EVALUATED IN A PROGRAM AT THE AMES RESEARCH CENTER. FORECASTS OF THE AVIONICS STATE OF THE ART AND THE AIRSPACE SYSTEM REQUIREMENTS FOR THE 1980s ARE BEING DEVELOPED UNDER CONTRACT. USING THESE FORECASTS, INTEGRATED SYSTEM CONCEPTS WILL BE GENERATED AND EVALUATED. THE AVIONICS INDUSTRY IS BEING SURVEYED SIMULTANEOUSLY TO INSURE THAT PLANS OR ACTIVITIES FOR THE 1980 PERIOD ARE CONSIDERED IN OUR CONCEPTUAL SYSTEM DEFINITIONS.

FLIGHT DEMONSTRATION OF THE SEPARATE SURFACE ATTITUDE COMMAND CONTROL SYSTEM IS ALREADY WELL UNDERWAY ON A BEECHCRAFT MODEL 99 COMMUTER AIRLINER. THE SYSTEM AS FLYING AND AS ENVISIONED IN APPLICATION IS A "SINGLE THREAD" OR NONREDUNDANT CONCEPT THAT IS PARALLEL TO THE PRIMARY SYSTEM.

PORTIONS OF THE CONTROL SURFACES HAVE BEEN SEPARATED FROM THE PRIMARY PILOT CONTROL LOOP AND ARE DEDICATED TO THE ELECTRONIC COMMAND. AUTHORITY OF THE ELECTRONIC COMMAND



INTEGRATED AVIONICS SYSTEM CONCEPTS

AVIONICS SYSTEM RESEARCH

SEPARATE SURFACE STABILITY AUGMENTATION SYSTEM FLIGHT EVALUATION



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Figure 7

IS LIMITED BY THE PHYSICAL SIZE OF THE DEDICATED SURFACE. CONSEQUENTLY SHOULD A FAILURE OCCUR, IT WOULD BE PERCEIVED BY THE PILOT AS AN OUT-OF-TRIM CONDITION, EASILY OVERRIDDEN WITH THE NORMAL FLIGHT CONTROL SYSTEM. PRELIMINARY RESULTS FROM THE FLIGHT PROGRAM AND SUBJECTIVE EVALUATION OF THE PILOTS INDICATE THAT THE CONCEPT IS PROVIDING THE ANTICIPATED IMPROVEMENTS IN BOTH FLYING AND RIDE QUALITIES.

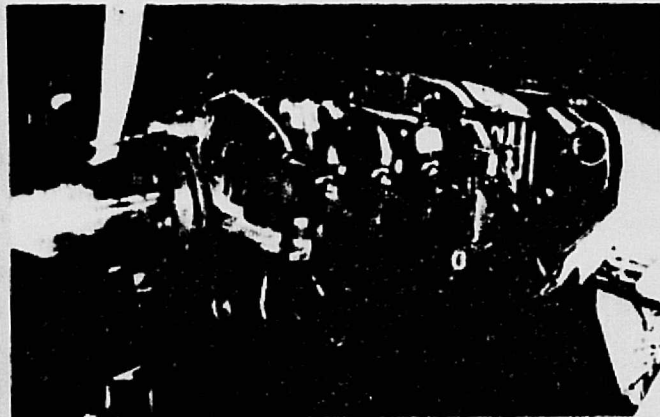
ENVIRONMENTAL IMPACT

THE ENVIRONMENTAL PROTECTION AGENCY HAS ISSUED EMISSION STANDARDS GOVERNING GENERAL AVIATION PISTON ENGINES MANUFACTURED AFTER 1979. FEDERAL AIR REGULATION PART 36F PRESCRIBES ALLOWABLE NOISE LEVELS FOR PROPELLER DRIVEN AIRCRAFT. IN SOME AREAS, BUSINESS JET AIRCRAFT ARE RESTRICTED FROM CERTAIN OPERATIONS UNDER STRICT LOCAL CURFEWS. NEW AIRPORT CONSTRUCTION IS INFLUENCED BY ENVIRONMENTAL CONCERNS. ENVIRONMENTAL IMPACT OF THE GENERAL AVIATION FLEET MUST BE REDUCED BOTH TO MEET REGULATIONS AND TO BECOME A MORE ACCEPTABLE PARTNER.

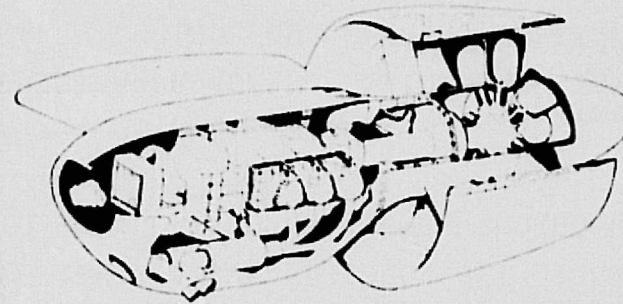
FIGURE 8 ILLUSTRATES SEVERAL NASA PROGRAMS TOWARD REDUCED ENVIRONMENTAL IMPACT. NASA, THE FAA AND TWO RECIPROCATING ENGINE MANUFACTURERS HAVE BEEN WORKING TO STUDY EXHAUST EMISSIONS FROM 10 REPRESENTATIVE AIRCRAFT PISTON ENGINES AND TO DETERMINE THE EFFECT OF VARYING THE FUEL/AIR RATIOS OF EMISSION LEVELS AND OPERATION.

IT HAS BEEN DEMONSTRATED THAT NOISE FROM PROPELLER DRIVEN AIRPLANES CAN BE REDUCED TO BARELY PERCEPTIBLE LEVELS. THESE SAME DEMONSTRATIONS ALSO SHOW TOTALLY UNACCEPTABLE PENALTIES ON PERFORMANCE AND EFFICIENCY. NASA EFFORTS IN PROPELLER NOISE REDUCTION SEEK TO DEVELOP AND DEMONSTRATE ADVANCED NOISE REDUCTION TECHNOLOGY THAT WILL MEET OR

RESEARCH TO REDUCE ENVIRONMENTAL IMPACT



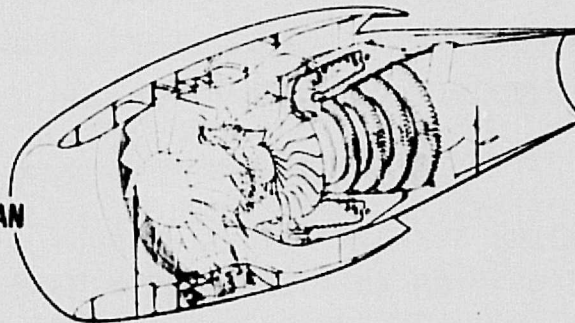
PISTON ENGINE EXHAUST EMISSION REDUCTION



PROPELLER/PROPULSOR NOISE REDUCTION

QUITE CLEAN GENERAL AVIATION TURBOFAN

HIGH BYPASS RATIO TURBOFAN



EXISTING CORE ENGINE

NASA HQ RT76-2087 (3)
1-29-76

EXCEED NOISE STANDARDS WITH MINIMUM PERFORMANCE PENALTY AND NO COMPROMISE IN FLIGHT SAFETY. DETAILED MEASUREMENTS WILL ALSO BE MADE OF NOISE SIGNATURES OF SEVERAL TYPICAL LIGHT AIRCRAFT. THESE DATA WILL PROVIDE A BASELINE FOR FUTURE WIND TUNNEL AND FLIGHT TESTING OF NEW PROPELLER CONCEPTS.

SMALL TURBOFAN ENGINES USED IN BUSINESS JET AIRCRAFT ARE FACED WITH THE SAME ENVIRONMENTAL CONSTRAINTS AS LARGE TRANSPORT ENGINES. SIGNIFICANT RESEARCH HAS BEEN DEVOTED TO REDUCING THE NOISE AND EMISSIONS FROM TRANSPORT-SIZE TURBOFAN ENGINES. NASA NOW HAS AN EXPERIMENTAL PROGRAM TO DEMONSTRATE APPLICABILITY OF LARGE ENGINE RESEARCH TO THE SMALL TURBOFAN. THE PROGRAM IS CALLED THE QUIET CLEAN GENERAL AVIATION TURBOFAN (QCGAT) PROGRAM.

APPLICATION OF NEW TECHNOLOGY TO THE BUSINESS JET WILL ULTIMATELY RESULT IN QUIETER AIRCRAFT. HOWEVER, MOST OF THE MORE THAN 1,600 BUSINESS JET AIRCRAFT CURRENTLY FLYING IN NORTH AMERICA ARE POWERED BY ENGINES NOT SPECIFICALLY DESIGNED FOR LOW NOISE. NASA, JOINTLY WITH THE FAA AND THE NATIONAL BUSINESS AIRCRAFT ASSOCIATION, CARRIED OUT A PROGRAM TO DOCUMENT APPROACH NOISE LEVELS OF REPRESENTATIVE BUSINESS JET AIRCRAFT. FOR EXISTING AIRPLANES, TEST DATA ARE REQUIRED TO FORMULATE OPERATIONAL PROCEDURES TO MINIMIZE COMMUNITY NOISE EXPOSURE.

FIVE AIRCRAFT WERE FLOWN THROUGH FOUR DIFFERENT APPROACHES. USING THE STANDARD THREE-DEGREE APPROACH AS A BASELINE, DATA WERE TAKEN DURING FOUR-DEGREE, THREE-DEGREE LOW DRAG AND TWO-SEGMENT APPROACHES. IN EACH CASE, DEFINITE NOISE REDUCTIONS WERE RECORDED. HOWEVER, IT WAS ALSO SHOWN THAT THE PILOT WORKLOAD PROGRESSIVELY INCREASED.

AGRICULTURAL AIRCRAFT

IN ADDITION TO THE TECHNICAL PROGRAMS JUST DESCRIBED, AN ADDITIONAL AREA HAS BEEN IDENTIFIED AS A POSSIBLE CANDIDATE FOR SPECIFIC NASA RESEARCH EFFORTS. THE AREA UNDER CONSIDERATION, AS REPRESENTED IN FIGURE 9, IS THE DEVELOPMENT OF NEW TECHNOLOGY TO INCREASE PRODUCTIVITY OF AIRCRAFT USED IN AGRICULTURE. PENDING RESULTS OF FURTHER ANALYSIS, A PROGRAM WILL BE DEFINED AND IS BEING PLANNED.

A BRIEF STUDY BEGUN BY NASA IN NOVEMBER 1975 IS DOCUMENTING THE SIGNIFICANT ROLE PLAYED BY AIRCRAFT IN U. S. AND WORLD FOOD PRODUCTION AND IS IDENTIFYING AREAS WHERE NASA RESEARCH MAY PROVIDE ADDITIONAL BENEFITS.

IN 1974, THE RESEARCH AND DEVELOPMENT COMMITTEE OF THE NATIONAL AGRICULTURAL AVIATION ASSOCIATION (NAAA) PERFORMED AN ANALYSIS WHICH INDICATES THAT A 10 PER CENT INCREASE IN THE \$100 BILLION ANNUAL FARM PRODUCTION CAN BE DIRECTLY ATTRIBUTED TO THE USE OF AIRCRAFT.

THIS \$10 BILLION RETURN IS GENERATED FROM AERIAL APPLICATION OF SEEDS, FERTILIZER AND PESTICIDES TO 200 MILLION ACRES EACH YEAR. THIS ACRE TOTAL REPRESENTS MULTIPLE APPLICATIONS TO THE SAME CROPLAND, SINCE OF THE 350 MILLION ACRES UNDER CULTIVATION IN THE U. S., IT IS ESTIMATED THAT ONLY 15 PER CENT (52.5 MILLION ACRES) BENEFIT FROM AERIAL APPLICATION.

USE OF THE AIRPLANE AND ITS BENEFITS CAN BE SIGNIFICANTLY INCREASED IF SEVERAL PROBLEMS CAN BE OVERCOME. CHEMICAL DRIFT CONTROL AND THE RELATED PROBLEM OF PRECISE

PROBLEMS IN AGRICULTURAL AVIATION

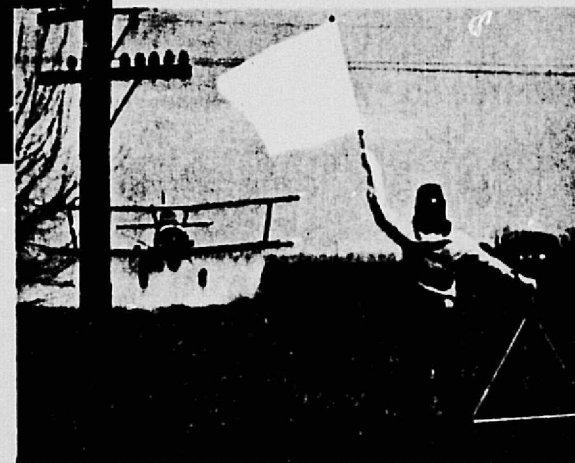


**DISTRIBUTION
SYSTEMS
ACCURACY**



- CORROSION CONTROL
- SHORTFIELD PERFORMANCE
- FERRY SPEED
- SWATH GUIDANCE

- HANDLING QUALITIES
- MANEUVERABILITY
- PERFORMANCE



**AERODYNAMIC INTERACTIONS
WITH DISTRIBUTION SYSTEM
(SWATH CONTROL)**

NASA HQ RT76 2087 (3)
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APPLICATION ARE THE MAJOR CONCERNS. AVAILABLE EQUIPMENT AND TECHNIQUES OFTEN APPLY TWICE THE AMOUNT OF CHEMICALS ACTUALLY REQUIRED. CORROSION OF THE AIRCRAFT STRUCTURE IS ANOTHER MAJOR CONCERN. AIRCRAFT EFFICIENCY IN TERMS OF TAKEOFF AND LANDING, CRUISE OR FERRY SPEED, APPLICATION SPEED, TURNING AND STABILITY AND CONTROL CAN BE IMPROVED. A SYSTEMS APPROACH TO DESIGN OF BOTH AIRPLANE AND APPLICATION EQUIPMENT AS A UNIFIED DISPERSAL SYSTEM APPEARS TO BE THE MOST APPROPRIATE FIRST STEP.

STRONG SUPPORT FOR NASA RESEARCH IN THIS AREA HAS BEEN SHOWN BY BOTH THE INDUSTRY AND USER COMMUNITY.

SUMMARY

GENERAL AVIATION RESEARCH IS RECEIVING STRONG AND GROWING SUPPORT WITHIN NASA. PROBLEMS AND CONCERNS OF THE INDUSTRY REFLECTED BY RECOMMENDATIONS OF THE RESEARCH AND TECHNOLOGY ADVISORY COUNCIL'S PANEL ON GENERAL AVIATION ARE BEING ADDRESSED IN OUR RESEARCH PROGRAMS. NASA'S COMMUNICATION WITH THE INDUSTRY AND USER COMMUNITY CONTINUES TO IMPROVE, ON A FORMAL LEVEL AND THROUGH MORE DIRECT INVOLVEMENT IN THE RESEARCH ACTIVITIES.

RESULTS FROM SEVERAL RECENT PROGRAMS ARE BEING USED BY INDUSTRY IN DESIGNING NEW AIRCRAFT. WHILE MANY TECHNICAL PROBLEMS REMAIN, MECHANISMS FOR DEVELOPING SOLUTIONS THROUGH NASA RESEARCH NOW EXIST.